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star maps inside!

Does life really need liquid water? p. 38

November 2006

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Observing, telescopes, origin and fate of the cosmos

NEW RESEARCH

The hunt for magnetars*

Astronomers zero in on ultramagnetized stars that unleash mammoth bursts of energy p. 32

OBSERVING

Get ready for Leonid meteors p. 74

View a rare transit of Mercury p. 80

* A fast-spinning neutron star with an intense magnetic field that powers some of the strongest X- and gamma-ray flares known.

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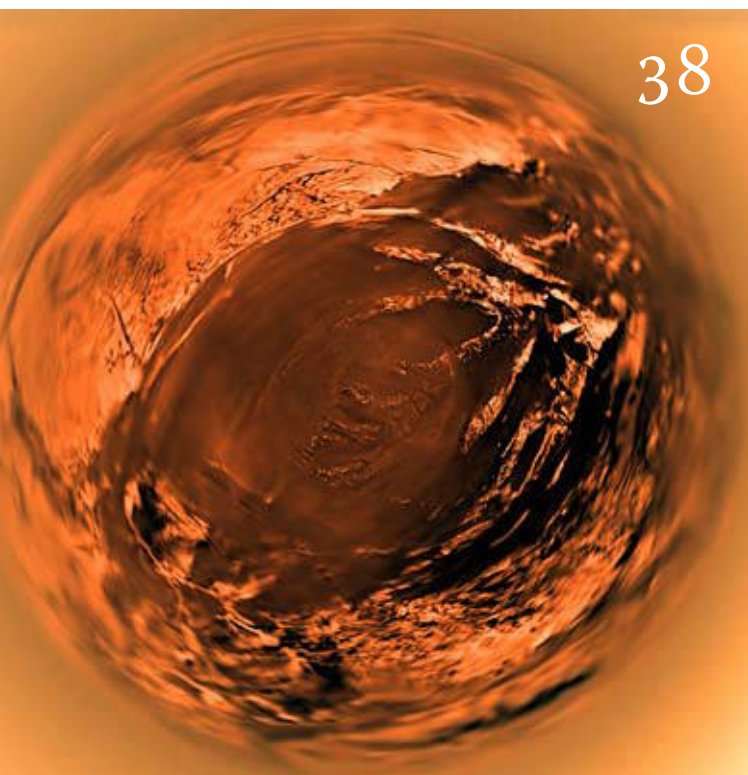
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Astronomy

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november 2006



ERICH KAROSCHKA/ESA/NASA/UNIV. OF ARIZONA



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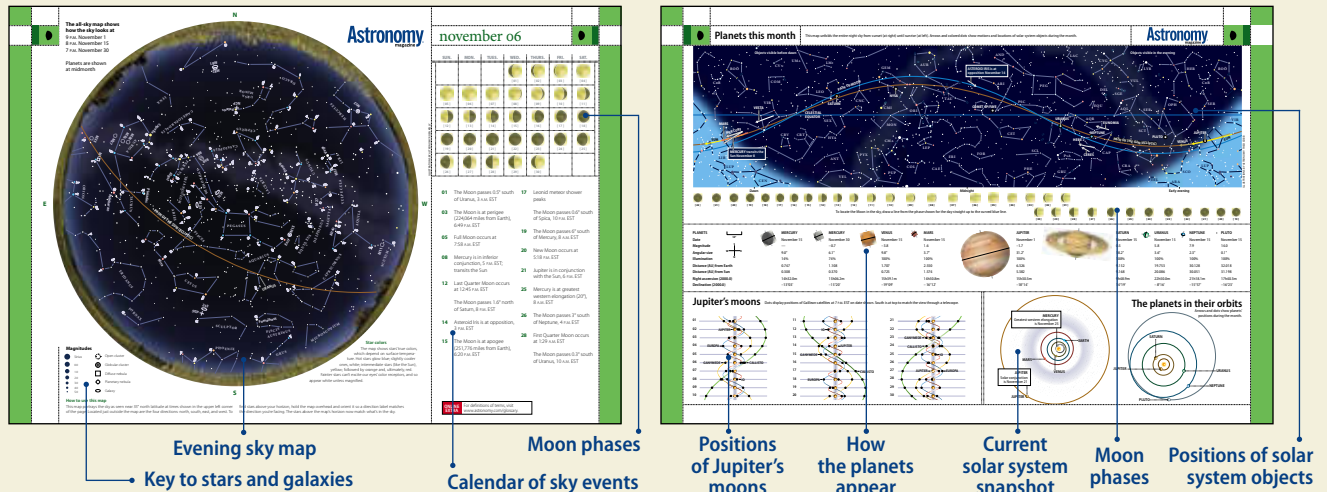
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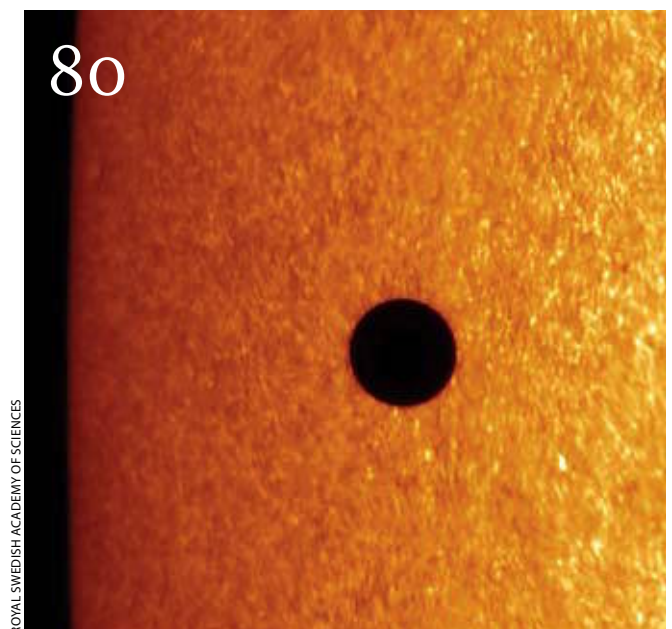
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Ultramagnetic weirdness

Every era of astronomy has its new, weird, virtually unexplainable objects. In the 1960s, it was quasars and pulsars. More recently, there was dark matter, the Kuiper Belt, gamma-ray bursts, and the biggest, strangest discovery of all: dark energy. Now, we have few odd discoveries

that equal magnetars. The story of magnetars dates to 1987, when astrophysicists Robert Duncan of the University of Texas at Austin and Christopher Thompson of the University of Toronto came up with the idea of supermagnetized neutron stars. The astronomers theorized magnetars would be the strongest magnetic fields known in the cosmos. But, if they existed, where would these strange creatures of the cosmos be?

In "On the hunt for magnetars" (page 32), *Astronomy* Contributing Editor Steve Nadis investigates how magnetars traveled from theory to reality. The turning point came in 1998, when a team led by astronomer Chryssa Kouveliotou showed that a soft gamma-ray repeater named SGR 1806-20 was likely a magnetar with a magnetic field more than a million billion times stronger than Earth's. A couple of months after that find, a huge burst of high-energy radiation slammed into Earth's atmosphere. Astronomers found it emanated from SGR 1900+14, which Kouveliotou and her team subsequently determined was another magnetar.

But the biggest shock wave of energy was yet to come. On December 27, 2004,

astronomers recorded the highest energy blast ever detected from outside the solar system. This time it was SGR 1806-20, which scorched the space surrounding it (including us, 50,000 light-years away) with more energy than the Sun produces in a quarter billion years. What stars could possibly produce such incredible energy blasts? The answer lies wrapped in one of the most compelling stories of astronomical detective work of recent years.

Planetary and galactic explorers have another subject on their minds: "Does life really need water?" (page 38). In this story, Nadis explores the possibilities of other solvents, such as methane and ammonia, that could support living creatures. These liquids are found in a few places in the solar system and maybe deep within the galaxy beyond.

Yours truly,

David J. Eicher
Editor

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Editor David J. Eicher

Art Director LuAnn Williams Belter

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Editorial Assistant Valerie Penton

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Assistant Art Director Tonya J. Limberg

Illustrators Theo Cobb, Rick Johnson, Roen Kelly

Production Coordinator Joni Hauser

CONTRIBUTING EDITORS

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Circulation Coordinator Valerie Jensen

ADVERTISING DEPARTMENT

(888) 558-1544

Advertising Sales Manager Howard Hoerl

hhoerl@astronomy.com

Advertising Sales Representative Ken Kozerski

kkozerski@astronomy.com

Ad Services Representative Allison King

aking@kalmbach.com

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PHOTOGRAPHED WITH A "DEEP SKY IMAGER PRO" AND A 10-INCH LX200.

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Meteorites rock

Bravo on your August issue. I've always been interested in meteorites and have read many articles about them. The August 2006 *Astronomy* was a good overview of a wide-ranging subject and included excellent graphics. — **ROBERT SMITH**, KINGSPORT, TENNESSEE

A great job

The August 2006 issue was, indeed, a "Special issue" on "Rocks from space!" It is one of the best publications I have ever seen on meteorites. The articles are exceptional and the illustrations superb.

After more than 40 years' experience, including stints as

a mineralogist with the U.S. Geological Survey, an associate editor for *The Mineralogical Record*, and as a student of Professor Brian H. Mason (one of the foremost researchers on meteorites), I am now retired but still keenly interested in the subject. — **R. C. ERD**, CANE HILL, ARKANSAS

Corrections

I noted two errors in the "Rocks around the clock tonight" sidebar on page 77 of the August 2006 issue. The first was the statement that meteors must be closer than 120 miles (190 kilometers) to be visible. In fact, meteors seen below 25° elevation are farther away.

Second, regarding a meteor's speed entering Earth's atmosphere — the lowest possible speed is about 25,000 mph (40,300 km/h). The maximum, at Earth's perihelion, is 165,500 mph (265,000 km/h). The August issue stated a figure about 4,000 mph less. — **WAYNET. HALLY**, HIGH BRIDGE, NEW JERSEY

In the August issue, on page 37, the glossary term "isotope" should have been defined as: different forms of the same element with the same number of protons and, therefore, the same atomic numbers, but with different numbers of neutrons and, therefore, different masses.

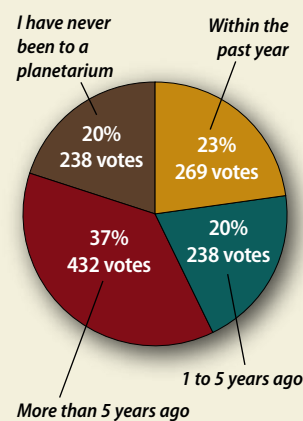
— **ASTRONOMY EDITORS**

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103? 109? 110?

Why doesn't *Astronomy* magazine recognize M110? You call it NGC 205. Fair enough. But in your *Atlas of the Stars*, you say Messier had 109 entries. You even include the debated M102. But not even in the Messier Marathon section does it include M110. This makes no sense! — **OLIVER TUNNAH**, ST. ANNES, BRISTOL, ENGLAND



Charles Messier's (1730–1817) list of deep-sky objects has grown since its inception. Messier published his initial tally of 45 objects in *Memoires de l'Academie* for 1771, released in 1774. Two supplements were then produced, one by Messier in 1780 that brought the total to 68. Then, Messier's colleague Pierre Méchain added 35 objects. In the 1920s, French astronomer Camille Flammarion uncovered evidence of Messier's observations of six more objects, bringing the total to 109.

Most astronomers consider this catalog of 109 objects as the historical Messier list. Only in 1967 did British astronomy writer Kenneth Glyn Jones suggest the addition of NGC 205, which Messier undoubtedly observed and sketched, to the list as M110. Some astronomers accept this change and others do not, believing the statute of limitations for tinkering with Messier's list ran out long before the 1960s. — **DAVID J. EICHER**, EDITOR

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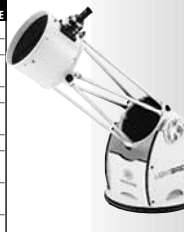


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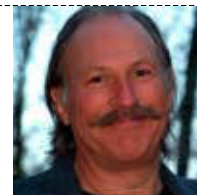
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Playing favorites

A star party is a festival of favorites.

People look at their pet sky objects using their best eyepieces. After an hour, you conclude everyone has excellent taste: They like the same things you do. The universe may contain 125 billion galaxies, thousands of NGC targets, 109 Messier objects,

and 8 observable planets, but dollars-to-donuts, we all will return to the same ones.

This is more than mere inertia. Countless comments from backyard astronomers throughout the decades, and outright votes at astronomy clubs since 2004, make it clear what our peers regard as the *crème de la crème*. See if you feel the same way.

This level of agreement often surprises raw beginners, who imagine experienced observers adore thousands of celestial objects more-or-less equally. Not so. In fact, let's stop pretending we even *like* sparse open clusters like M36, when nice rich ones like M11 — and especially the globulars — beat them coming and going, backward and forward.

Start with some favorite naked-eye objects. In the **favorite constellation** category, the top two winners are Orion and Scorpius, in that order. Not Ursa Major, even though civilians name the Big Dipper ahead of everything else. Some of us say Sagittarius or Cygnus, while our friends Down Under often vote for Crux. A few serious amateurs choose something truly deviant like Gemini, for reasons only their therapists understand.

Favorite challenging naked-eye object: This probably depends on where you live. In Los Angeles, the Moon is sometimes hard to find, so you might pick M45 as a faint and elusive treasure, while those in the country would be more apt to say, "Seeing more than eight Pleiads." So which is it? The naked-eye view of the Hercules globular? The Moon-size blob of galaxy M33? (Ya gotta have superb conditions for

that.) The unnamed open cluster that surrounds Orion's "belt" in black skies? Not enough votes in yet.

Naked-eye spectacle: Here, everyone picks either a total solar eclipse or an aurora.

Star name: Winning entries are usually Betelgeuse, Vega, or Arcturus. Contrarians go for esoteric ones like Zosma. Nobody ever picks poor Spica. What about hardest-to-pronounce? If you can say "biscuit mixer" 10 times, you'll have no trouble pronouncing Vindemiatrix.

LET'S STOP PRETENDING we even *like* sparse open clusters like M36.

Favorite binocular target: Cowinners are the Pleiades (M45), the Andromeda Galaxy (M31), and the Beehive Cluster (M44).

Telescopic nebula: Here there's unanimity. You knew it. The Orion Nebula (M42).

Nebula using a filter: The envelope please. The winner: the Veil Nebula (NGC 6992–5) in Cygnus through an OIII filter.

Telescopic galaxy: Sorry, large apertures only. Two winners share the prize: The Whirlpool Galaxy (M51) and NCG 4565 in Coma Berenices.

Double star: One winner alone: Albireo. We all love Albireo. Plus, it's got your high-school colors — blue and gold.

Telescopic planet: Split decision. Some say Jupiter, others pick Saturn.

Lunar feature: In the mountain-range category, it's the Apennines. In the crater category, it's Copernicus. Tycho is famous, but doesn't get a single vote.

Star cluster: Again, it's unanimous. The Great Globular (M13) in Hercules. People who live in the far south pick Omega (o) Centauri, and you can't blame them.

Variable star: I love Lambda (λ) Tauri with its 1-magnitude metamorphosis and 4-day period. Here-today-gone-tomorrow Mira is a candidate, too. You'd think the popular vote would go to Delta (δ) Cephei, the famous Cepheid prototype, plus it's circumpolar. But no, the crowds have spoken. The winner is Algol (Beta [β] Persei).

Let me add a few weirder categories that nobody's yet voted on.

Favorite hemisphere: Although the Southern does have Crux, Omega Centauri, and a superior Milky Way, I'd pick Northern, thanks to its better-looking galaxies.

Most vividly colored star: We'd have to disqualify the blues because none is sufficiently saturated. And there's not one green star in the heavens. We're forced to pick a red. I'd give the honors to R Leporis or Mu (μ) Cephei through any telescope. Both are visible this month.

Strangest-colored star: Use medium power to check out the pastel companion to Cor Caroli in Canes Venatici. Have your friends vote on what color they see. Everyone says something different. Some say violet, some yellow. Weird.

Most-disappointing object through a telescope: I'd pick Mars.

Worst constellation: Should we say Leo Minor? Musca the Fly? There are a dozen equally pathetic candidates.

Space-choices are dynamic, just like the votes on those oldies radio stations. This isn't the last word. Post your nominees on my web site: www.skymanbob.com, and we'll keep a tally. Next year, maybe we'll have new favorites and even weirder categories. ■

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A view to an eclipse

Here's a little astronomical riddle for you: Which star in the late-autumn sky winks at us once every 2 days, 20 hours, and 49 minutes? Each wink lasts about 10 hours. If you identified the mystery star as the eclipsing binary Algol (Beta [β] Persei), you're right!

In its parent constellation, Algol represents the head of the mythical Medusa, a hideous snake-haired creature slain by Perseus. "Algol" comes from the Arabic *Ra's al Ghul*, the "demon's head." Such sinister connotations suggest the ancients were aware of this star's odd behavior and regarded it with suspicion. However, no evidence exists anyone officially described Algol's variability until the late 17th century, when Italian astronomer Geminiano Montanari reported its brightness changes.

From 1782 to 1783, young English astronomer John Goodricke observed this star and noted the fading occurred at regular intervals. He surmised a dark, orbiting companion partially eclipsed Algol. A planet, he wondered? Not quite.

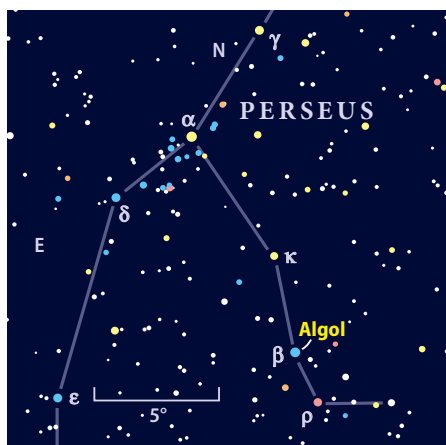
A century later, spectroscopic studies showed that Algol is a close, unequally bright binary system whose orbital plane is

nearly edge-on to our line of sight. As a result, the fainter star periodically passes in front of the brighter one and produces an eclipse that dims the system's brightness.

Even though we can observe an eclipse of Algol with the unaided eye (the star fades from a maximum magnitude of 2.1 to a minimum of 3.4), few observers choose to view the event after they learn it lasts 10 hours. At a meeting of the American Association of Variable Star Observers (AAVSO) a few years ago, I chatted with Marvin Baldwin and Gerard Samolyk — two renowned eclipsing-binary observers. I sheepishly admitted that, although I had studied a fair number of eclipsing variable stars, I had yet to observe an eclipse of Algol. Marv and Gerry pointed out that I didn't need to observe Algol for the full 10 hours because most of the "action" happens during a 6-hour span centered around mid-eclipse. Encouraged by their suggestions, I made plans to view Algol's next favorable eclipse.

Beginning 3 hours before the predicted time of mid-eclipse, I compared Algol to nearby stars of known magnitude to get a brightness estimate (refer to the map at left). I recorded the date, time, and magnitude in my observing log. Every 15 minutes, I made a follow-up observation. At first, the changes were subtle, but as mid-eclipse approached, Algol faded precipitously. The return was just as rapid, and by the end of the 6-hour run, Algol had regained its former brightness.

If you're not inclined to commit to a 6-hour observing run, try giving Algol a



USE THIS finder chart to locate Algol in the night sky. ASTRONOMY: ROEN KELLY

HOW-TO TIP

WHEN AND WHERE TO WITNESS AN ALGOL ECLIPSE

To help plan observations, here's an eclipse schedule for North America. The geographical areas listed offer the best opportunities for viewing the entire eclipse. To monitor an entire eclipse, select a site that affords a clear view of Algol and its surrounding stars throughout the 6 hours. Whether you opt for a "full run" or a casual "quick look," take the opportunity to see the "demon star" wink. — G. C.

MID-ECLIPSE IN NORTH AMERICA October (All times EST)

30/31 — 4:40 A.M., western areas

November

2/3 — 1:29 A.M., all areas

5/6 — 10:18 P.M., eastern areas

22/23 — 3:12 A.M., western and central areas

25/26 — 12:01 A.M., central and eastern areas

December

12/13 — 4:55 A.M., western areas

15/16 — 1:44 A.M., all of areas

18/19 — 10:34 P.M., eastern areas

"quick look." The evening *before* a scheduled eclipse, estimate its brightness. At the time of mid-eclipse the next night, give Algol another look. You'll be surprised how much fainter it appears.

Questions, comments, or suggestions? E-mail me at gchaple@hotmail.com.

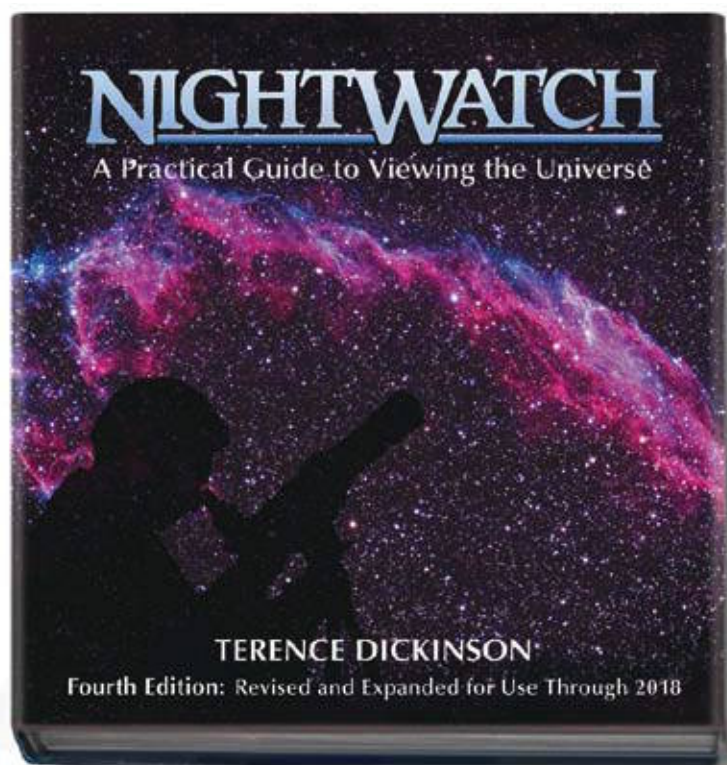
Next month: some holiday gift ideas. Clear skies. ■

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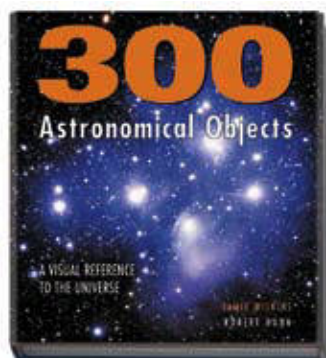
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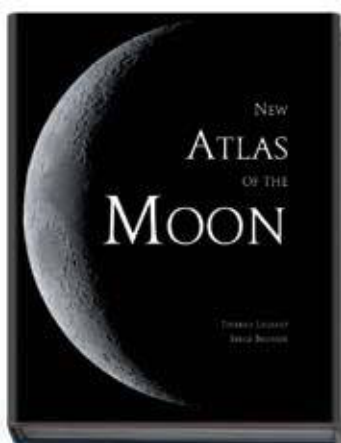


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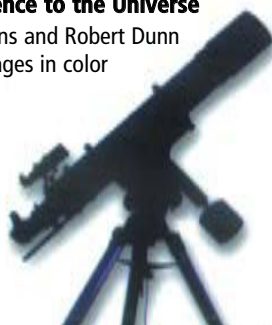
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Entertain the Queen

“Here the Milky Way is so rich that an observer hardly needs any guidance; he is sure to stumble upon interesting sights for himself.” This is how Garrett Serviss describes the binocular view of Cassiopeia the Queen in his *Astronomy with an Opera Glass* (1888). Serviss’ charming

book introduced the idea that people could use binoculars to view the heavens. Of course, binoculars made back then don’t compare to the quality found in even the least expensive binoculars today. But his equipment’s low quality didn’t deter Serviss from viewing the binocular universe from his home in Brooklyn, New York.

One of Cassiopeia’s sights Serviss mentioned lies near the star Zeta (ζ) Cassiopeiae. You’ll find Zeta just south of Schedar (Alpha [α] Cassiopeiae), which marks the lower-right corner of the Queen’s “W” pattern. Through binoculars, 4th-magnitude Zeta’s distinct aquamarine hue contrasts nicely against Schedar’s orangish tint.

Zeta lies at the end of a semicircular asterism of seven fainter stars that Serviss described as an “array of stars ... in a broken half-circle, which may suggest the notion of a crown.” Together, they resemble a backward

3 or a miniature Corona Borealis. Because older depictions of the constellation show Zeta representing the Queen’s head, “Cassiopeia’s crown” seems an appropriate name for this little asterism.

Let’s go deeper into the constellation by following the zigzag path along the Cassiopeia five-star “W” to Ruchbah (Delta [δ] Cassiopeiae), at its lower-left corner. Aim half a binocular field to the southwest of Ruchbah toward 5th-magnitude Phi (ϕ) Cassiopeiae. You’ll see a second fainter star just to Phi’s southwest as well as a tiny smear of dim starlight to the north. Together, they form the **Owl Cluster**, NGC 457. The two brightest stars mark the owl’s eyes, while the fainter suns outline its body and outstretched wings. Some observers imagine a dragonfly here, while others see the movie character ET. Although most binoculars reveal the cluster, you’ll probably need at least 15x to see any hint of these heavenly creatures.

Most studies indicate Phi doesn’t actually belong to NGC 457, but, instead, just happens to fall along the same line of sight. Strangely enough, Phi appears to move through space in the same direction as the cluster. This usually indicates a physical association. If that’s so, then at the cluster’s distance of 9,000 light-years, Phi would have to be an incredible 250,000 times more luminous than our Sun.

Next, let’s stop by open cluster **M103**, located to the other side of Ruchbah. My 10x50s show this group as a small triangular patch of starlight nestled in a pretty Milky Way field. I can make out four or five separate stars here. The rest of its 170 members

HOW-TO TIP

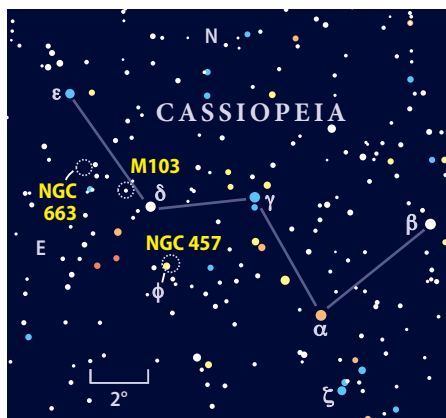
BINOCULAR SUPPORT

I closed the August column (“My favorite month”) with a tip on how to hold binoculars steadily by hand. To get the most out of an observing session, however, I prefer to put the binoculars on some sort of separate support. This makes it easier to go back and forth between them and a star chart. Photographic tripods alone, however, are usually too short, and their legs often get in the way.

I recommend a neat binocular mount designed by Terry Alford from Gray, Tennessee. It fits on top of a tripod and raises the binoculars to eye level when viewing skyward.

The mount is easy to make. Drop by the online extra of this column at Astronomy.com this month for photographs and a description of Terry’s clever design.

Be sure to send me a note, either by e-mail to phil@philharrington.net or in care of *Astronomy* magazine, if you make your own. I’d love to hear about it. — P. H.



THIS FINDER CHART will help you navigate your way to this month’s targets.

ASTRONOMY: ROEN KELLY

pool their faint light to create what looks like a tiny arrowhead. Others think M103 resembles a handheld fan.

Scan the area around M103, and you will notice the hazy glow of **NGC 663** a little east of the halfway point between Ruchbah and the star Segin (Epsilon [ϵ] Cassiopeiae). In fact, you may see it before you even notice M103. NGC 663 looks like an unresolved blur of light through my 10x50s, while my 16x70s add a few feeble points of light.

Next month, we’ll take the sky’s camel for a ride down a celestial cascade. Till then, remember, two eyes are better than one! ■

ONLINE EXTRA

To learn more about Terry Alford’s binocular mount, visit www.astronomy.com/toc.

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Astron**ews**



NURSERY EXPOSED. Scientists assembled an infrared portrait of the Orion Nebula (M42) from nearly 10,000 Spitzer Space Telescope images.



26

Spitzer snaps infrared Orion Nebula

NASA's Spitzer Space Telescope looked behind the Orion Nebula's (M42) glowing veil of gas to reveal new details of star formation in one of the night sky's most-observed targets.

The telescope, which is sensitive to heat emitted by warm dust, took images that reveal about 2,300 young stars surrounded by dusty disks that could be forming planets. The census also found 200 newborn stars that haven't yet made disks.

"This is the most complete census of young stars with disks in the Orion cloud complex," says Thomas Megeath of the University of Toledo, Ohio, who led the research. "When I first got a look at the image, I was immediately struck by the intricate structure in the nebulosity."

Spitzer's Infrared Array Camera (IRAC) collected nearly 10,000 exposures to compose this image. In this false-color view, reddish swirls

of dust form the backdrop for the nebula's sprinkling of embryonic stars.

Most stars form in crowded environments like M42, say astronomers, so mapping objects and processes in the Orion Nebula star cluster is key to understanding the details of how stars form.

M42 lies about 1,450 light-years from Earth. The Spitzer scene spans about 20 light-years. — **JEREMY MCGOVERN**

26 **Keck, Gemini watch red-spot encounter**

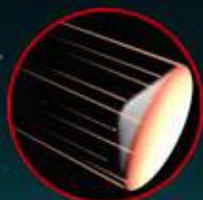
28 **Jules Verne prepares for flight**

30 **Titan may be land of lakes**

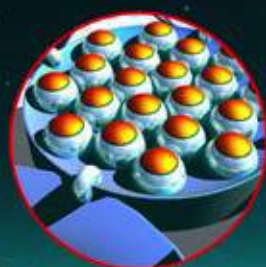
31 **Cluster scores a bull's-eye**



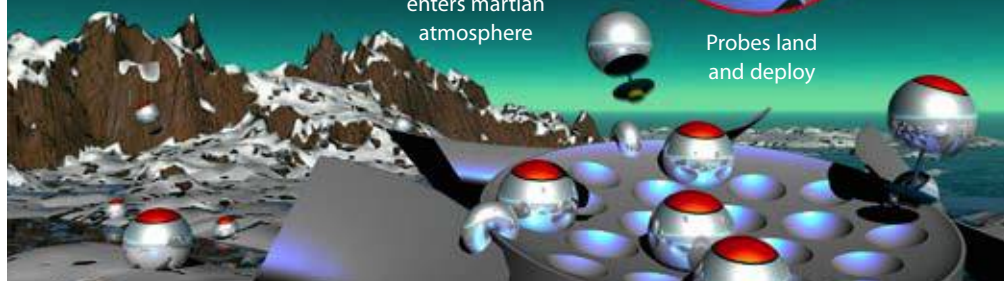
Spacecraft delivers probes to Mars



Probe package enters martian atmosphere



Probes land and deploy



MIT/R. D. GUS FREDERICK

MARS SWARM. Clusters of spherical mini-probes could be ready to explore Mars in the next decade. The probes could explore lava tubes and steep-sided valleys too tough for rovers to handle.

MIT pitches baseball-size Mars probes

One day, a swarm of hopping mini-probes may fan out across the martian landscape — at least, if one Massachusetts Institute of Technology researcher has his way.

Steven Dubowsky, director of MIT's Field and Space Robotics Laboratory, envisions thousands of fuel-cell-powered, baseball-size probes exploring the Red Planet en masse. Each probe will weigh about 4 ounces (113 grams), carry cameras or other sensors, and communicate with other

nearby probes via a local area network. A swarm of these bouncing, hopping, and rolling craft could cover 50 square miles (130 square kilometers) of martian terrain in 30 days.

It would take 1,000 of Dubowsky's mini-probes to equal the weight of NASA's Spirit or Opportunity rover. He says he's ready to begin terrestrial testing of prototypes and thinks his mini-probes would be ready for a flight to Mars in about 10 years. — **LAURA LAYTON**

GRACE finds earthquake changes

NASA's twin Gravity Recovery and Climate Experiment (GRACE) satellites have detected crustal changes caused by 2004's massive Indian Ocean earthquake. The discovery, reported in the August 3 issue of *Science*, is the first time satellites have detected such changes.

The 9.1-magnitude December 2004 temblor was Earth's third largest quake since 1900. It released the energy equivalent of 475 million tons of TNT. The resulting tsunamis killed some 300,000 people and displaced more than 1 million.

"The earthquake changed the gravity in that part of the world in two ways that we were able to detect," explains Shin-Chan Han of Ohio State University, Columbus.



ANDERS GRAVIN

GNARLY. Tsunamis rolled ashore following the massive December 26, 2004, earthquake off Sumatra. The temblor created crustal changes picked up by gravity-sensing satellites.

The massive quake lifted part of the seafloor, which altered Global Positioning Satellite measurements of the area. It also changed the rock density beneath the ocean floor, which minutely altered the region's gravitational attraction. The two GRACE satellites, in orbit since 2002, detected both effects. — **FRANCIS REDDY**

QUICK TAKES

Watch your step

Virginia-based space tourism firm Space Adventures Ltd. is adding a **personal space-walk** onto its \$20 million International Space Station tours. Expect to pay another \$15 million for the excursion.

More than a paint job

Los Angeles astronomy icon **Griffith Observatory reopens** this month following a \$93 million renovation. Roughly 70 million people visited the institution between 1935 and 2002, making it the world's most visited public observatory.

Hit the shower

Peter Jenniskens of California's SETI Institute and Caltech's Jérémie Vaubaillon predict a **meteor outburst September 1, 2007**. That's when Earth passes near the center of a dust trail from the long-period Comet Kiess (C/1911 N1). The astronomers say the 2-hour outburst will peak at 11h37m UT. The shower, which the astronomers are calling the Alpha Aurigids, is expected to be rich in bright meteors.

Reflect this

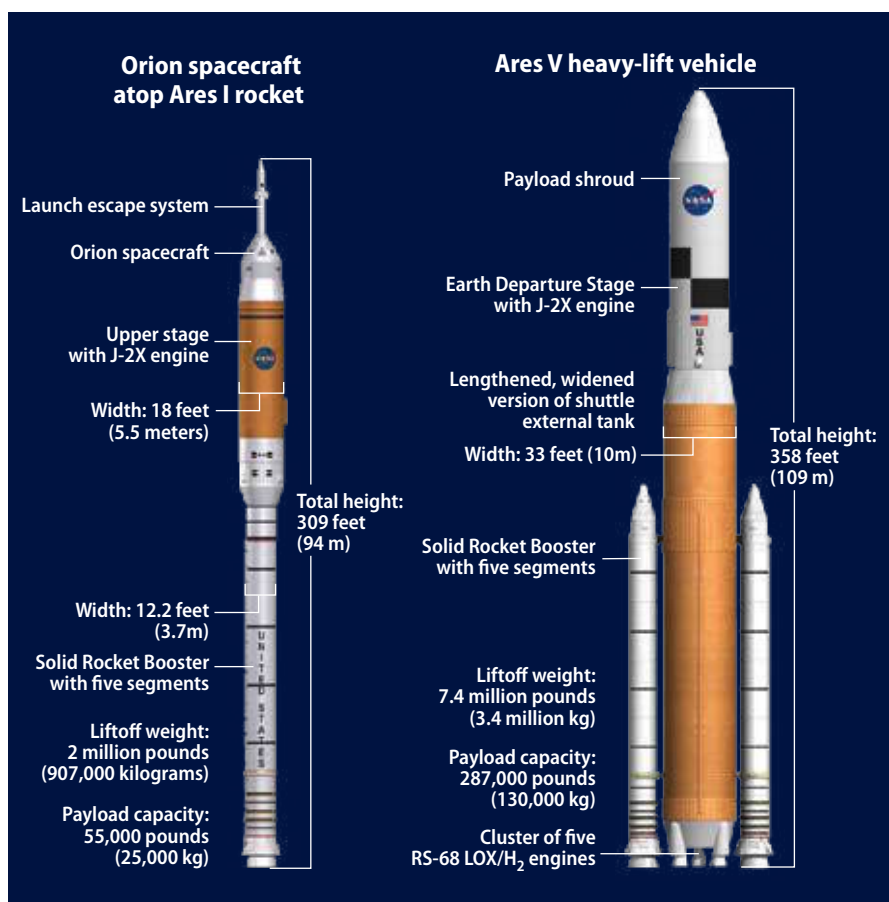
The **Thirty Meter Telescope (TMT)** project has moved to detailed design. TMT's primary mirror would span 98 feet (30 meters) — 3 times the diameter of today's largest telescopes.

We'll be too old

NASA chief Michael Griffin says the agency will begin assessing possible approaches in 2007 for **sending humans to Mars**. But he doesn't foresee an actual mission for at least 20 years.

To Keck with it

Keck Observatory's Sam Ragland used Arizona's Infrared-Optical Telescope Array (IOTA) in Arizona to view **old red giant stars** in unprecedented detail. One-third of the 56 stars surveyed showed patchy disks possibly caused by large surface spots, shock waves, or even planets. — **F. R.**



FUTURE FLEET. NASA's Ares rockets will replace expensive shuttle-derived upper-stage engines with an Apollo-descended J-2X. The Ares V's first stage will fire a cluster of five RS-68 engines developed for Boeing's Delta IV. Both rockets will use extended versions of the space shuttle's 4-segment Solid Rocket Boosters.

NASA names CEV, rockets

On August 22, NASA announced its name for the Crew Exploration Vehicle: Orion. U.S. astronaut Jeff Williams on the International Space Station let the name slip when a message he taped in advance was accidentally broadcast.

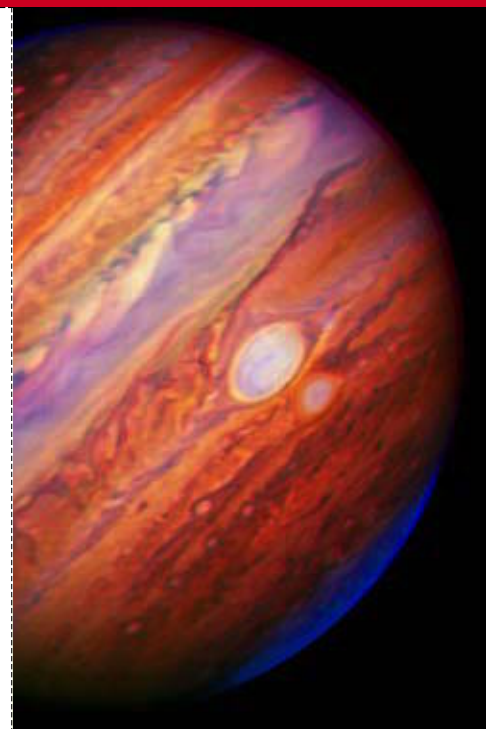
On June 30, NASA said its new line of post-shuttle-era launch vehicles would be called Ares. The Crew Launch Vehicle, which will replace the space shuttle as early as 2011, is now named Ares I. The massive heavy-lift rocket designed to loft cargo headed for the Moon later in the decade is Ares V.

Ares, the Greek name for Mars, is a nod to the agency's vision of one day sending astronauts to the Red Planet. The numerical designations salute the Apollo-

era Saturn I and Saturn V rockets, the first large U.S. launchers specifically designed for human spaceflight.

Both of the new vehicles use components derived from the space shuttle program. But NASA announced it has moved away from using pricey Space Shuttle Main Engines (SSMEs). Ares I's upper stage will use a J-2X engine, an updated and simplified descendant of the upper-stage engines on Saturn rockets.

The Ares V's first stage will use a cluster of RS-68 engines modified from Boeing's Delta IV rocket. This is the first large liquid-fueled engine developed in the United States since the SSMEs. And NASA can buy four RS-68s for the current price of one SSME. — **F. R.**



CATEGORY 5. At near-infrared wave-lengths, Red Spot, Jr., remains darker than the Great Red Spot, which suggests the older storm's clouds climb higher.

IMKE DE PATER, MICHAEL WONG (UC BERKELEY)/AL CONRAD (KECK)/CHRIS GO (CEBU, PHILIPPINES)

Keck, Gemini watch red-spot encounter

Amateur and professional astronomers watched with delight in mid-July as Jupiter's two red spots grazed one another. Astronomers using the Keck II and Gemini North telescopes in Hawaii captured near-infrared views of Jupiter's Great Red Spot and Oval BA — nicknamed Red Spot, Jr.

In infrared, both spots look whitish, not red. Both spots are giant storm systems. The Great Red Spot has been seen on the planet for more than 3 centuries, but Earth-size Red, Jr., is a newcomer. It formed between 1998 and 2000, when three long-enduring white ovals merged. On February 27, Philippine amateur astronomer Christopher Go discovered Oval BA had turned brick-red.

What reddens Jupiter's superstorms? Imke de Pater at the University of California, Berkeley, says, "The jury is still out." — **L. L.**

Earth's crust explored

Integrated Ocean Drilling Program scientists report they've bored through intact ocean crust off Central America's west coast and into a fossil magma chamber. They collected samples of gabbro, a type of hard, black rock that forms as molten magma slowly cools.

Doug Wilson of the University of California, Santa Barbara, led the study, which appears in the May 19 *Science*. "Finding the right place to drill was probably the key to this success," he says.

"Sampling a deep fossil magma chamber will allow us to compare its composition to overlying lavas," explains Jeff Alt of the Uni-



INTEGRATED OCEAN DRILLING PROGRAM

DRILL BIT. JOIDES Resolution has recovered 147 miles of ocean core since 1985.

versity of Michigan, co-chief scientist for the expedition. Geologists can then test models of oceanic crust's structure and formation. Using the U.S.-operated research drilling ship JOIDES Resolution, the team spent 5 months boring a hole 0.8-mile deep (1.4 kilometers) in the Pacific Ocean's Cocos Plate. — F. R.



November 1981

25 years ago in Astronomy

Editor Richard Berry and Associate Editor Robert Burnham pulled out all the stops in November 1981 with a 25-page article on Voyager 2's August 1981 Saturn flyby. The next mission to the planet, they wrote, "will probably drop probes into the atmospheres of Saturn and Titan, and continue the reconnaissance that Voyager has so tantalizingly begun."

Voyager 2 was the third spacecraft to fly past Saturn, after Pioneer 11 (1979) and Voyager 1 (1980), but it remains the only spacecraft to fly by Uranus (1986) and Neptune (1989).

In 2004, the Cassini mission achieved Saturn orbit. Cassini dropped the Huygens probe, which sampled Titan's atmosphere and beamed back surface images.



November 1996

10 years ago in Astronomy

The phrase "life on Mars" was on everyone's lips in August 1996. That's when a team led by David McKay of NASA's Johnson Space Center announced unusual chemical and physical residue in a Martian meteorite. In "Was there life on Mars?" *Astronomy* Associate Editor Robert Naeye detailed the meteorite's history and examined the evidence McKay's team uncovered.

While the team's study hasn't convinced scientists, it has an important legacy. Analysis techniques will be refined with an eye to the day when scientists can examine fresh Mars rocks up close. — F. R.

BRIEFCASE

Aerosol climate

Atmospheric aerosols may play a strong role in climate changes, at least locally. Ian Koren of Israel's Weizmann Institute of Science and Yoram Kauffman of NASA's Goddard Space Flight Center in Greenbelt, Maryland, suggest tiny airborne particles — including pollution, sea salt, and desert dust — may cause local climate change that offsets warming from greenhouse gases. A local rise in aerosols can increase cloud cover, which reflects sunlight and cools the region. — L. L.

DSN woes

Two of the four bearings in the base of NASA's 230-foot-wide (70 meters) Deep Space Network (DSN) antenna in Madrid need replacement. Engineers found the problem during a planned maintenance period, but the extensive repair now will keep the antenna offline into 2007. Project managers for the downlink-heavy Cassini and Mars Reconnaissance Orbiter missions have worked out new data-transmission priorities to cope with the antenna's loss. — F. R.

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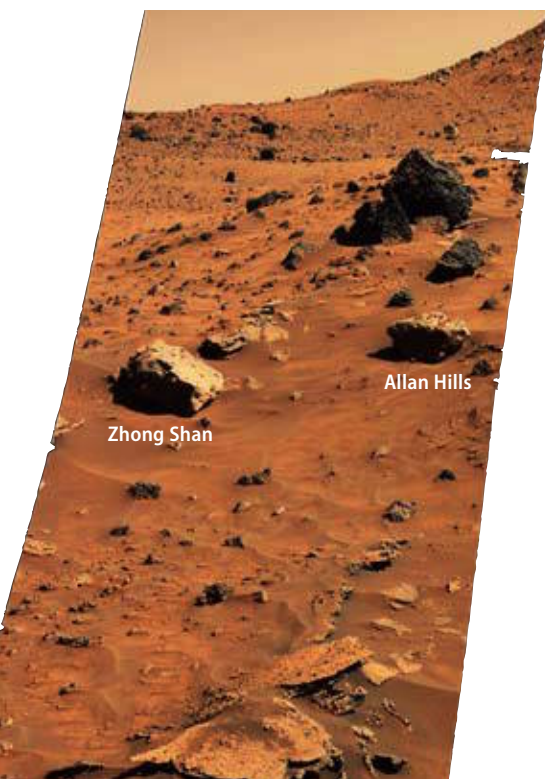
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ROCKFALL. NASA's Spirit scores a pair of meteorites. NASA/JPL-CALTECH/CORNELL

Spirit finds possible meteorites

NASA's Mars Exploration Rover Spirit may have imaged two meteorites at its winter outpost inside Gusev Crater.

On June 16, the rover's panoramic camera returned a color mosaic of hilly, sandy terrain at a spot named Low Ridge Haven. The scene contains a pair of light-colored, smooth rocks that mission scientists suspect are meteorites.

The rocks' unusual shapes and thermal emissions resemble those of Heat Shield Rock. Spirit's twin rover, Opportunity, found this basketball-size iron meteorite in January 2005 in Meridiani Planum.

The science team has named the rocks Zhong Shan and Allan Hills, in keeping with a campaign to name soils and rocks at Spirit's winter haven after places in Antarctica. Zhong Shan is a Chinese base; Allan Hills is a spot where researchers have found many martian meteorites. — F. R.

Jules Verne prepares for flight

With space shuttle Discovery's successful July flight, NASA is resuming assembly of the International Space Station (ISS). The agency aims for ISS to be able to host six astronauts by 2009. Part of what will make this possible is a new generation of support spacecraft.

The first of these, the European Space Agency's (ESA) Automated Transfer Vehicle (ATV), is finally slated to appear next year. Delayed several years due to a series of fabrication problems, this vehicle will be critical to full exploitation of the enlarged ISS.

The ATV will also put on a good show for amateur satellite observers, especially on its first flight (now set for May 2007). That's when it will spend a week in orbit performing a series of ISS approaches, fly-arounds, and departures prior to its final docking. About the size of a London double-decker bus, and nearly as large as a Russian Salyut-class space station, the ATV will be big, bright, and flashy as it turns its four solar arrays toward the Sun.

The spacecraft's specifications are impressive. It's a fat cylinder 32-feet (9.8 meters) long and 16.8-feet (4.5m) wide, with 237 square feet (22 square meters) of solar panels, and a habitable volume of 1,589 cubic feet (45 cubic meters). It will weigh 45,745 pounds (20,750 kilograms), of which 35 percent is deliverable cargo. That's 3 times the capacity of a Russian Progress supply drone. Cargo could be equipment, food, water, or propellant.

ESA plans to fly one mission per year and has budgeted for at least seven vehicles. Each will be launched aboard an Ariane 5 booster from the space center at Kourou, French Guyana, in South America. The first carries the name of Jules Verne.

Jules Verne's automated rendezvous and docking will use newly developed navigation and control computers. It normally



FERRY. The European Space Agency's Automated Transfer Vehicle completed acoustic testing in July.

will take 3 to 5 days from launch to link-up. The first mission, however, is a test flight, and the craft will spend perhaps twice as long in free flight. Jules Verne will perform repeated approaches to, circumnavigations of, and departures from ISS. Best of all, observers will be able to follow many of these maneuvers visually.

Because the ATV depends on Russian-built docking mechanisms, it can dock only at the aft (axial) port of the Russian Zvezda module. All supplies must be loaded into containers narrow enough to pass through Russia's standard 31.5-inch (80 centimeter) circular hatches. On the U.S. side, shuttle-delivered supplies pass through square hatches 51 inches (130 cm) on a side, which allows transfer of refrigerator-size racks of scientific apparatus. So, in this regard only, the ATV takes a step backward with regard to station logistics.

But in the years following the space shuttle's 2010 retirement, vehicles like the ATV will be important. Improved ATV versions will join a Japanese sister spacecraft called the H-II Transfer Vehicle (HTV), now being developed, plus still-to-be-designed commercial transports. Orbital traffic will be fast, frequent, and often easily visible to amateur astronomers. — JAMES OBERG

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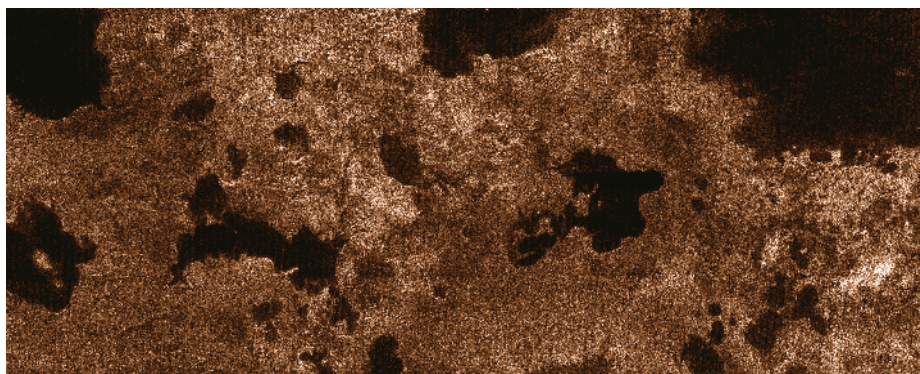
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NASA/JPL

LAKESIDE. Dark, featureless patches in Titan's arctic zone may be methane lakes. Cassini's radar imager acquired this view, centered near 80° north, 92° west, July 21. The image spans about 260 miles (420 km).

Titan may be land of lakes

Cassini mission scientists think they've finally found Titan's long-suspected methane lakes. On July 21, the radar system aboard NASA's Saturn-orbiting Cassini spacecraft peered through Titan's orange fog and imaged a region in the northern hemisphere. The images clearly show dark, well-defined but featureless areas linked by channels.

The "lakes" lack any radar variation, which leads researchers to think they're seeing smooth liquid surfaces. "The evidence is largely morphological," says Cassini team member Rosaly Lopes. "We're comparing the area to the great lakes of Minnesota."

Some lakes reach 19 miles (30 kilometers) across. "It's the most exciting pass we've had so far," Lopes says. "Finally, we have a source of the methane. Dozens!"

The lakes lie between 75° and 80° north. Many are egg-shape or curved, but several have the appearance of liquid-filled volcanic craters. In June 2005, Cassini's imaging system found a single kidney-shape dark area near Titan's south pole — suggestively near stormy methane clouds.

Many researchers see the new images as support for the idea that methane rain falls there today. Because such lakes may wax and wane over time, and winds may alter the roughness of their surfaces, repeat coverage of these areas should test whether, indeed, these smooth features are fluid bodies.

If the land of lakes turns out to be what scientists suspect it is, Titan would become the only world other than Earth known to have surface liquids. — **MICHAEL CARROLL**

Does the Milky Way blow axion bubbles?

Anatoly Svidzinsky of Texas A&M University in College Station challenges the widely held notion that a black hole inhabits our galaxy's core. Instead, he says, oscillating bubbles of dark matter — specifically, hypothetical particles called axions — create the regular infrared and X-ray flares astronomers detect there.

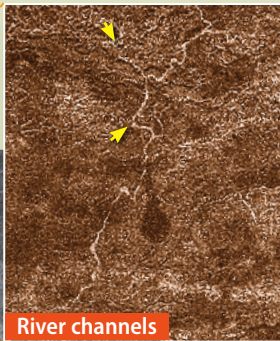
The flares erupt about every 20 minutes, a regularity that's hard to explain for a matter-gobbling black hole. But Svidzinsky's bubbles naturally oscillate with this period. And stable axion bubbles would weigh up to 2.5 million Suns, within the mass range estimated for the galactic center's putative black hole.

Decaying axions could account for the galactic center's diffuse X-ray emission. But, says Konstantin Zioutas of Geneva's European Organization for Nuclear Research, gas hot enough to emit this radiation would move fast enough to escape the galaxy.

Radio interferometers capable of resolving compact objects at the centers of galaxies may allow scientists to distinguish oscillating dark-matter bubbles from a black hole. — **L. L.**

Titan's Xanadu resembles Earth

NASA's Cassini spacecraft spied earthlike features on Saturn's large moon Titan in April. Using radar, scientists imaged a surface swath more than 2,800 miles (4,500 kilometers) long.



River channels

Xanadu's west coast

Dune field



CONTINENTAL. Xanadu is one of Titan's brightest areas, measuring about 2,485 miles (4,000 kilometers) from its western to eastern "coasts." This portion of Cassini's 140- to 300-mile-tall (220 to 490 km) radar sweep, acquired April 30, spans the continent-like region. NASA/JPL



ESA/J. L. ATTELYN

CLUSTER DUO. Europe's Cluster spacecraft caught Earth's magnetosphere in a quick-change act.

Cluster scores a bull's-eye

The European Space Agency's (ESA) four Cluster spacecraft have been flying formation through Earth's magnetosphere since August 2000. Now, say researchers, the spacecraft observed a reconnection event — a spontaneous restructuring of Earth's magnetosphere.

A team led by Chijii Xiao of the Chinese Academy of Sciences in Beijing reported the results in the July 2006 issue of *Nature Physics*. On September 15, 2001, the Cluster probes found themselves surrounding a magnetic null point — center stage of the reconfiguration process — while a reconnection event was under way. The data provide the first 3-D portrait of a null point. — **L. L.**

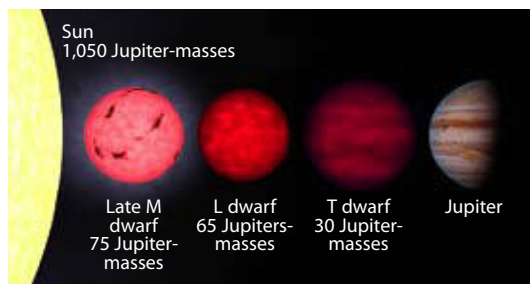
Chandra sees brown-dwarf X-ray flare

NASA's Chandra X-ray Observatory detected a bright X-ray flare from a surprising source — an M9-type brown dwarf named LP 944-20. This is the first time astronomers have seen such an outburst from what are thought to be quiescent objects.

"We were shocked," says Robert Rutledge of the California Institute of Technology in Pasadena. "We didn't expect to see flaring from such a lightweight object." A paper on the find appeared in the July 20 issue of *Astrophysical Journal Letters*.

The flare's energy is comparable to a small flare from the Sun. Scientists believe twisted magnetic fields powered the flare.

"This is the strongest evidence yet that brown dwarfs and possibly young giant planets have magnetic fields," says Caltech's Eduardo Martin. — **F. R.**



ROBERT HURT, SSC-CALTECH

SMALL STUFF. Despite their different masses, M-dwarf stars, brown dwarfs, and Jupiter all are about 10 percent of the Sun's size.

Cool dwarf is a solar neighbor

Astronomers have uncovered the closest known brown dwarf. Cataloged as DEN 0255-4700, an L-type dwarf, the object lies 16.2 light-years away in Eridanus and is 100 million times fainter than the Sun.

Edgardo Costa and Rene Mendez of the University of Chile in Santiago determined the object's distance and brightness. The new data rank DEN 0255-4700 as the 48th-nearest star or substellar object — one-third closer than any other known L-type dwarf.

Astronomers say DEN 0255-4700 has a surface temperature of just 2,600° F (1,427° C). The dwarf's L7.5-type spectrum reveals an outer atmosphere containing superheated water mixed with unusual elements like potassium, rubidium, and cesium.

Costa and colleagues measured the dwarf's distance by trigonometric parallax. Nearby stars appear to make tiny ellipses in the sky as Earth orbits the Sun. Over a period of 3 years, the team imaged DEN 0255-4700 and monitored its motion. The large size of the dwarf's annual ellipse demonstrates its proximity.

The study appeared in the September 2006 issue of *The Astronomical Journal*. — **F. R.**

Xanadu's surface has been changed by wind, rain, and flowing liquid — the same processes found on Earth. Channels cut through plains and meander across bright, hilly terrain,

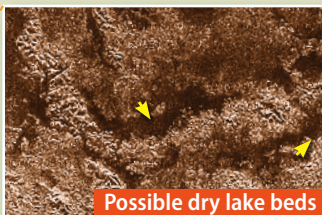


Mountain range

which gives way to mountains in the interior. Dunes traverse darker areas to the west of Xanadu.

An asteroid or volcanic eruption may have created some circular structures. Irregular flat-floor features may be dry lake beds that once contained liquid methane or ethane.

"Xanadu is no longer just a mere bright spot, but a land where rivers flow down to a sunless sea," says



Possible dry lake beds

Jonathan Lunine at the University of Arizona, Tucson. "We could only speculate about the nature of this bright country."

Xanadu appears to be the only large area on Titan not covered with "organic dirt" that falls out of the atmosphere. Methane rain from occasional storms is a prime suspect for cleaning the terrain.

Cassini will complete 29 flybys of Titan during the next two years, with 12 of them using radar. — **L. L.**



Possible crater or volcano

Xanadu's east coast

On the hunt for magnetars

Ten years ago, astronomers thought the idea of ultramagnetized stars was crazy. Now scientists know magnetars unleash mammoth bursts of energy. /// BY STEVE NADIS

In 1987, when Robert Duncan and Christopher Thompson first contemplated the existence of ultramagnetized neutron stars (which they later dubbed “magnetars”), they had a hard time convincing themselves the notion made sense. Five years later, when they got their first opportunity to present their ideas at a scientific conference, they were given just 3 minutes to make their case. Even as recently as 1998, at a meeting of the American Astronomical Society, Duncan was the

Steve Nadis is a frequent Astronomy contributor who enjoys writing about the weirdest astronomical objects.

last scheduled speaker at the 5-day event, seemingly lumped in the fringe category.

Six years later, in 2004, colleagues finally recognized Duncan and Thompson (now at the University of Texas and the University of Toronto, respectively) for their theoretical work on magnetars. Joining them was Chryssa Kouveliotou of the National Space Science and Technology Center (NSSTC) in Huntsville, Alabama, for observations that confirmed the scenario. The three received the Bruno Rossi Prize for outstanding contributions to high-energy astrophysics.

Thus, after years of doubts, astrophysicists at last acknowledged magnetars are real. These unusual objects constitute a

distinct class of pulsars. They are rapidly spinning, intensely magnetic neutron stars — remnants of massive stars that expired in fiery supernova blasts.

Armed with this knowledge, researchers then turned their attention to a broad range of questions, such as: Where do these curious objects, with the most powerful magnetic fields known to exist, come from? Or, put in other terms, what properties of progenitor stars give rise to magnetars rather than to black holes or other kinds of neutron stars?

Answering these questions can tell astronomers how abundant magnetically powered stars are, thereby providing clues to their astronomical importance.



Blasts from beyond

Scientists' acceptance that magnetars exist stems from a confluence of theory and observational data from some of nature's most impressive high-energy displays. For astronomers, says Thompson, the turning point came in 1998.

In May of that year, a team led by Kouveliotou showed that the soft-gamma-ray repeater (SGR) 1806–20, a pulsing X-ray source about 50,000 light-years from Earth, was likely a magnetar. Kouveliotou's team measured the rate at which the neutron star's spin was slowing down. A magnetic field could supply the drag to slow the star's rotation, but it had to be incredibly powerful. The scientists

IN A MAGNETAR'S GIANT FLARES, magnetic field lines break and reconnect, releasing a burst of energy. This process resembles solar-flare formation, except magnetars' flares are much more powerful. DON DIXON FOR ASTRONOMY

estimated a magnetic field of about a million billion (10^{15}) gauss. (Earth's magnetic field reaches just 0.6 gauss.)

Then, in August 1998, a powerful blast of gamma rays and X rays zapped Earth's outer atmosphere. The burst came from SGR 1900+14, some 20,000 light-years away in the direction of Aquila. Kouveliotou and her colleagues showed, based on the object's spin-down rate, that it, too, must be a magnetar.

On December 27, 2004, SGR 1806–20 let loose again. The eruption was the

most energetic blast from outside our solar system astronomers had ever recorded. In just 0.2 second, the magnetar released more energy than the Sun gives off in 250,000 years.

An international group of astronomers analyzing the December 27 event supported Duncan and Thompson's hypothesis that magnetar flares arise from twisting magnetic fields. These fields warp and strain the star's crust, creating shear across a region several kilometers long. This shear zone in some

ways resembles a geological fault that gives rise to an earthquake. Eventually, the star's crust cracks open.

This work answered some questions about the magnetar flares. But where do these overmagnetized neutron stars come from? "You can't see anything directly related to the progenitor [star] by looking at the flare," Duncan explains. Nevertheless, he adds, you can get hints simply by seeing where astronomers find magnetars.

Digging deeper to find answers

That's the approach Harvard astronomer Bryan Gaensler took when he searched the vicinity of a magnetar called AXP 1E 1048.1-5937, located roughly 9,000 light-years away in Carina. "It occurred to me that the environments around magnetars might tell us something about them," Gaensler recalls.

Gaensler's team studied the region's hydrogen emissions using Australia's Parkes radio telescope and the Australia Telescope Compact Array. The astronomers found a cavity carved out, they think, by stellar outflows from the magnetar's original star. Knowing that the star's mass is proportional to the cavity's size and expansion speed, the team deduced the progenitor star contained at least 40 times the Sun's mass.

Donald Figer of the Space Telescope Science Institute in Baltimore probed the connections between magnetars, their masses, and star clusters. Prior to SGR 1806-20's massive blast, Figer explored a cluster filled with young, massive stars that, coincidentally, contained that same magnetar. The most massive stars die first as

TWO TYPES OF BURSTERS

Magnetars break into two subclasses: soft gamma repeaters (SGRs) and anomalous X-ray pulsars (AXPs). Scientists know of five probable SGRs (four of which have been confirmed) and nine likely AXPs. Twelve of these 14 magnetars are in our galaxy; the Large and Small Magellanic Clouds hold one each.

As their name implies, SGRs emit "soft," or low-energy, gamma rays. Soft gamma rays have slightly higher energy than "hard" X rays. The giant flares from AXPs aren't as intense as those from SGRs, although they're still more intense than those from run-of-the-mill pulsars. — *Liz Kruesi*

supernovae, and less-massive stars expire later. Figer inferred that SGR 1806-20's progenitor had to be bigger than the biggest stars still standing in the star cluster; this implied a mass of at least 50 Suns.

Michael Muno of the University of California, Los Angeles, used a similar technique. While surveying the massive star cluster Westerlund 1 with NASA's Chandra X-ray Observatory, he found an X-ray pulsar lurking in the cluster's center. Based on the object's luminosity and spectrum, Muno deemed it a probable magnetar.

His survey showed that Westerlund 1 is teeming with high-mass stars, all roughly the same age, which placed a lower limit of about 40 solar masses on the magnetar's predecessor. It's intriguing, says Muno,

"that we have a good idea of the mass of the star this magnetar came from even though that star disappeared long before X-ray astronomy began."

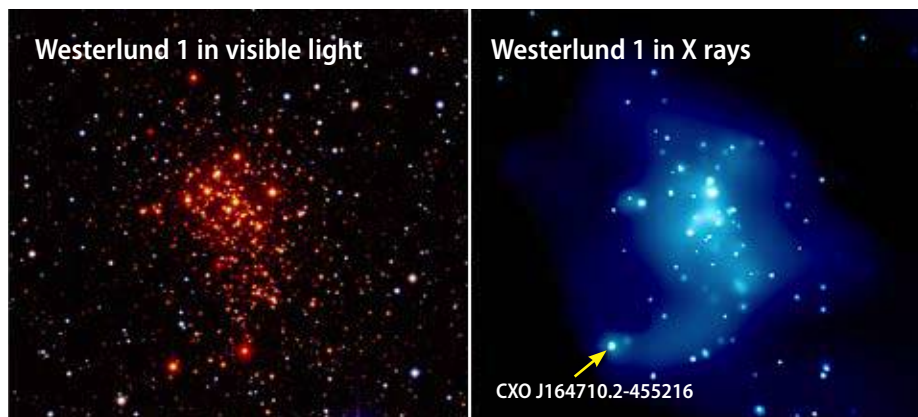
Both Muno and Gaensler believe the association of magnetars with massive star clusters looks strong. Moreover, both magnetars and high-mass clusters are rare, which makes chance alignments less likely.

Muno's next step is to confirm that his mystery source is, indeed, a magnetar. He has proposed to observe the object intermittently over the course of a year or more using the European Space Agency's XMM-Newton and NASA's Chandra X-ray observatories to see how its rotation period changes. This will enable him to estimate the object's magnetic-field strength. If this exceeds 10^{14} gauss, the object is a magnetar.

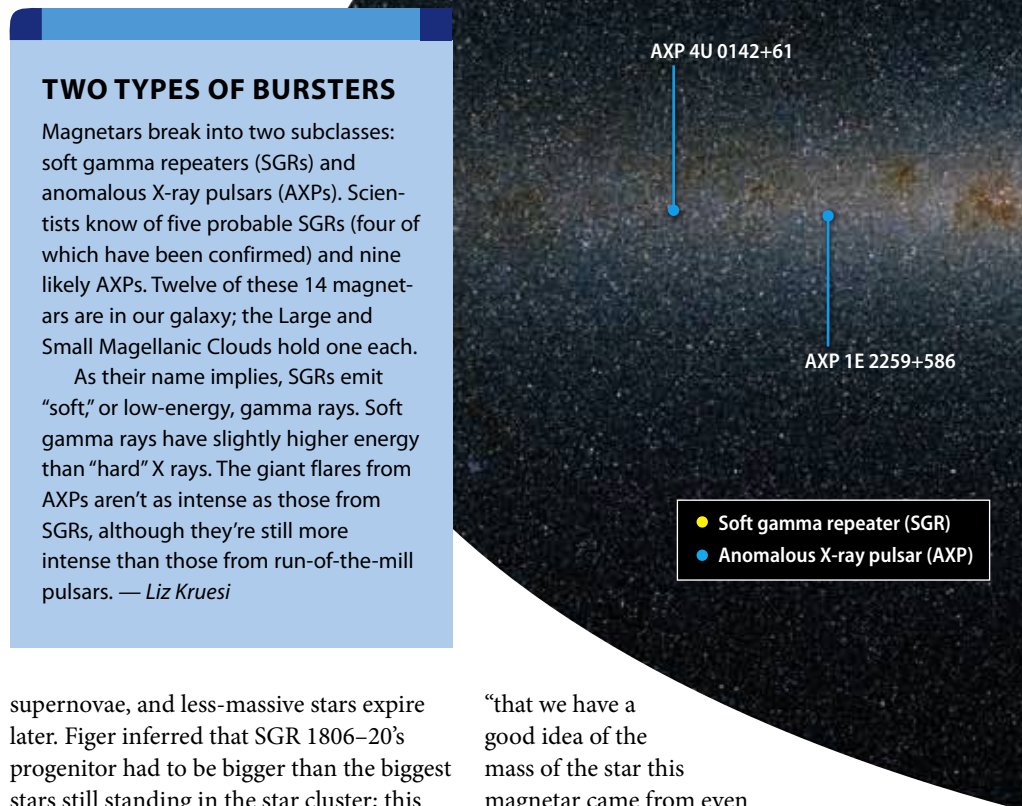
Searching star clusters

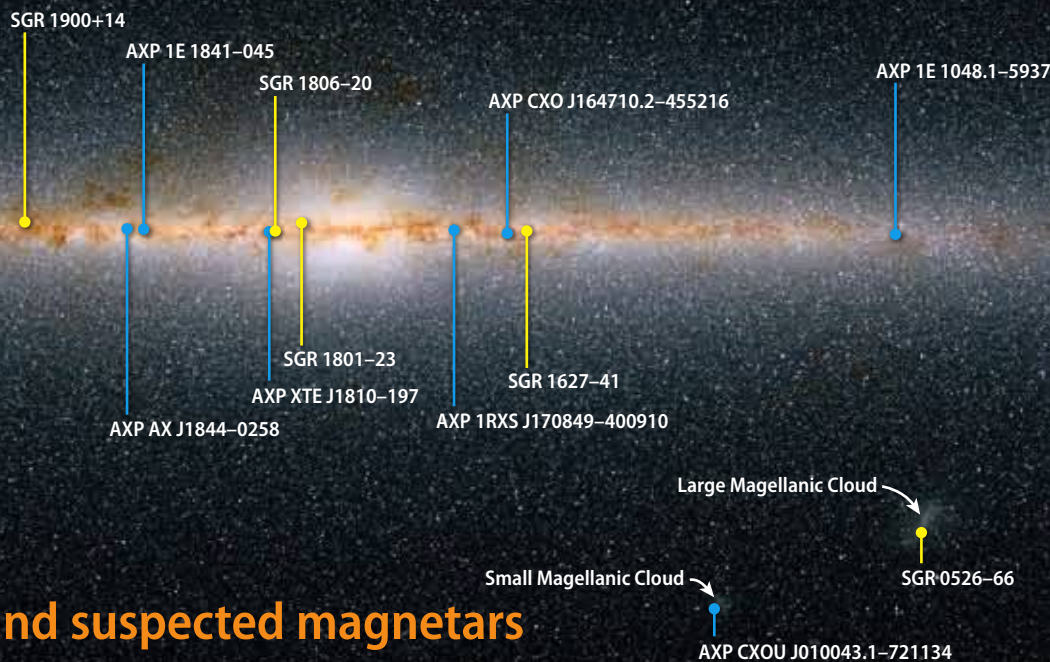
Figer is in the third year of an ambitious, 5-year effort aimed at finding all Milky Way star clusters containing at least 1,000 stars. To this end, he's utilizing infrared instruments at the Keck Observatory in Hawaii and aboard NASA's Hubble and Spitzer space telescopes to probe our galaxy's dusty disk. Figer predicts the final tally will be in the vicinity of 100 clusters.

"Our approach," says Figer, "is to identify the breeding grounds of magnetars — these massive clusters — and then use pointed observations to see how many magnetars are there."



MASSIVE STAR CLUSTER Westerlund 1 is home to the anomalous X-ray pulsar (AXP) CXO J164710.2-455216, a magnetar candidate. Astronomers discovered the object in 2005, and they hope to uncover additional magnetars as they explore the Milky Way's most massive star clusters. VISIBLE: ESO; X RAY: NASA/CXC/M. MUNO ET AL. (UCLA)





Known and suspected magnetars

MOST MAGNETAR CANDIDATES lie in the Milky Way's disk along the galactic plane, where the most massive stars now reside. Two other known magnetars are extragalactic, with one in the Large Magellanic Cloud (LMC) and the other in the Small Magellanic Cloud (SMC).

ASTRONOMY: ROEN KELLY; BACKGROUND: 2MASS/J. CARPENTER, M. SKRUTSKIE, R. HURT

Once Figer spots the clusters, Muno will do follow-up X-ray observations with Chandra. He'll look for pulsing X-ray sources and monitor their spin-down rates. So far, the team has been granted 11 hours on Chandra — enough to cover four objects. With any success, they'll then seek approval to plow through the entire list of about 100 clusters.

"With the discovery of a magnetar in Westerlund 1, we have good reason to believe this strategy will work," Muno says. "Finding a second case would show we weren't just lucky the first time and that we can find a significant number of objects."

By looking at many clusters, Muno and Figer hope to determine the masses of magnetar progenitor stars to within about 5 solar masses. Such precision is crucial for estimating the fraction of massive stars that become magnetars.

How many magnetars might our galaxy host? Figer believes astronomers have seen only about 10 percent of the Milky Way's massive clusters — dust shrouds the rest from view. By extension, this means we've discovered only about 10 percent of the galaxy's magnetars. Because scientists have identified 14 magnetars, the number anticipated in the Milky Way is around 100.

Gaensler, on the other hand, argues that if magnetars are actually spawned by 40-solar-mass stars, scientists have already found most of them. He, Muno, and Andrei Nechita, a Harvard University undergraduate, recently completed a broad archival search through XMM-Newton and Chandra data to look for pulsing X-ray sources that might be magnetars.

"From this huge search, we didn't find any magnetars except for the ones we already knew about," Gaensler says. "That tells us there aren't many magnetars out there, or they are much fainter than we thought, or they are often sleeping. Now we need to figure out which possibility is right."

90 percent to go

Recent findings point to a new class of transient magnetars whose X-ray brightnesses can vary wildly. This makes them detectable at some times and invisible at others. A team led by Alaa Ibrahim of George Washington University discovered, with the aid of NASA's Rossi X-ray Timing Explorer, just such a magnetar in 2003, when the object's luminosity suddenly increased by a factor of 100. A different group found another strong candidate at about the same time.

ASTROSPEAK

NEUTRON STAR

The dense remnant of a once-massive star's core formed in a supernova. Such stars may contain more than twice the Sun's mass crammed into a sphere roughly 12 miles (20 kilometers) across.

PULSAR

A rapidly rotating (many times a second) neutron star whose radiation beam passes Earth on each rotation, creating a pulse.

MAGNETAR

A neutron star with a magnetic field 1,000 times stronger than normal.

Ibrahim shares Figer's view that the galaxy may host 100 "live" magnetars. He notes this tally doesn't include magnetars that have spun down and lost their heightened powers. He believes the elusive, transient objects might resolve the discrepancy between the observed and expected magnetar populations. Muno and Figer are surveying for exactly this type of now-you-see-it, now-you-don't object. They're "trying to see whether there is a population of faint magnetars that hasn't turned up yet," says Muno.

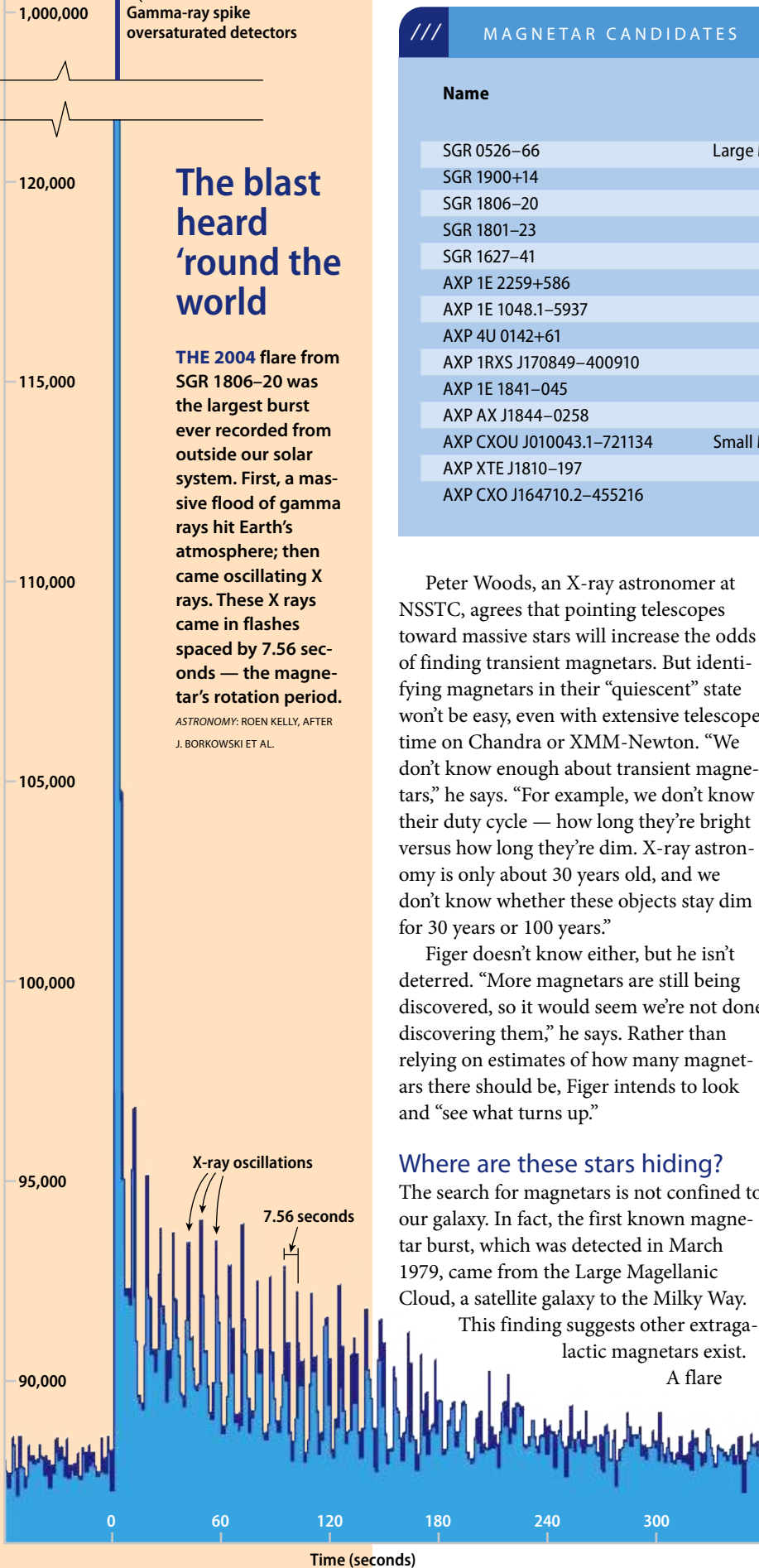
Name	Location	Rotation (seconds)	Year discovered
SGR 0526-66	Large Magellanic Cloud	8.0	1979
SGR 1900+14	Aquila	5.16	1979
SGR 1806-20	Sagittarius	7.56	1979
SGR 1801-23	Sagittarius	—	1997
SGR 1627-41	Ara	6.4	1998
AXP 1E 2259+586	Cassiopeia	7.0	1981
AXP 1E 1048.1-5937	Carina	6.4	1985
AXP 4U 0142+61	Cassiopeia	8.7	1993
AXP 1RXS J170849-400910	Scorpius	11.0	1997
AXP 1E 1841-045	Scutum	11.8	1997
AXP AX J1844-0258	Aquila	7.0	1998
AXP CXOU J010043.1-721134	Small Magellanic Cloud	8.0	2002
AXP XTE J1810-197	Sagittarius	5.5	2003
AXP CXO J164710.2-455216	Ara	10.6	2005

The blast heard 'round the world

THE 2004 flare from SGR 1806-20 was the largest burst ever recorded from outside our solar system. First, a massive flood of gamma rays hit Earth's atmosphere; then came oscillating X rays. These X rays came in flashes spaced by 7.56 seconds — the magnetar's rotation period.

ASTRONOMY: ROEN KELLY, AFTER J. BORKOWSKI ET AL.

Photons per second



Peter Woods, an X-ray astronomer at NSSTC, agrees that pointing telescopes toward massive stars will increase the odds of finding transient magnetars. But identifying magnetars in their “quiescent” state won’t be easy, even with extensive telescope time on Chandra or XMM-Newton. “We don’t know enough about transient magnetars,” he says. “For example, we don’t know their duty cycle — how long they’re bright versus how long they’re dim. X-ray astronomy is only about 30 years old, and we don’t know whether these objects stay dim for 30 years or 100 years.”

Figer doesn’t know either, but he isn’t deterred. “More magnetars are still being discovered, so it would seem we’re not done discovering them,” he says. Rather than relying on estimates of how many magnetars there should be, Figer intends to look and “see what turns up.”

Where are these stars hiding?

The search for magnetars is not confined to our galaxy. In fact, the first known magnetar burst, which was detected in March 1979, came from the Large Magellanic Cloud, a satellite galaxy to the Milky Way.

This finding suggests other extragalactic magnetars exist.

A flare

within 100 million light-years of Earth could be detected with current X-ray and gamma-ray instruments, provided the flare is as bright as SGR 1806-20’s 2004 event, says University of California, Berkeley, astronomer Kevin Hurley. “Since there are many galaxies within this range, we should see these events frequently,” he notes.

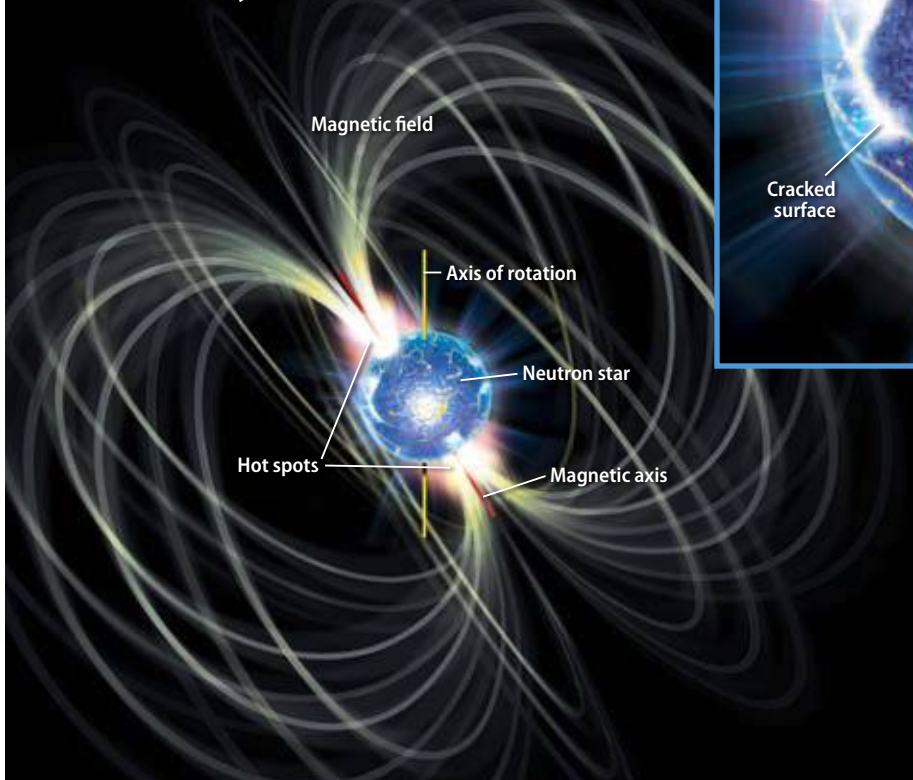
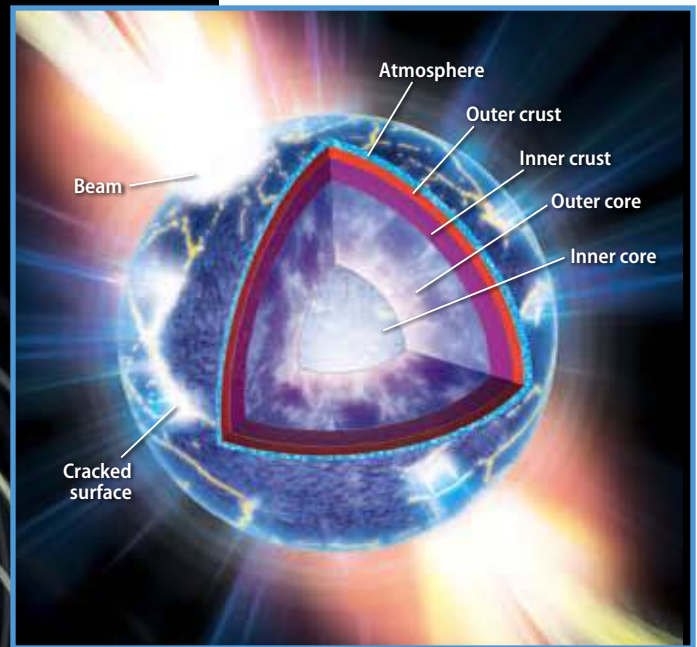
NASA’s Swift satellite, which launched in November 2004 to find gamma-ray bursts, can potentially “open up a new field of astronomy — the study of extragalactic magnetars,” says Duncan. For example, on September 6, 2005, Swift spotted a short-duration burst that might prove to be a magnetar flare emanating from a distant galaxy, although not all scientists accept this interpretation.

Swift and other instruments detected a November 3, 2005, burst from M81, a galaxy about 13 million light-years away. This, says Duncan, was “the first identified extragalactic magnetar flare outside the Local Group.” The flare’s energy release appears comparable to SGR 1806-20’s big blast in 2004.

For astronomers hunting extragalactic magnetars, NASA’s Swift is easily the best instrument around. Still, the satellite isn’t optimized for this task. Swift’s detectors are tuned to lower-energy (spectrally “softer”) events expected from neutron-star mergers. “With the right instruments flying,” Duncan explains, “we could detect a magnetar flare each week. Swift can’t find that many but may still spot an appreciable number over its lifetime.”

Inside a magnetar

A MAGNETIC FIELD 1,000 times stronger than normal elevates an ordinary pulsar to a magnetar. Drag from such an ultrastrong field slows a star's spin, which makes a magnetar rotate slower than a pulsar. *Right:* Astronomers think SGR 1806–20's 2004 flare began when the magnetar's surface cracked. Based on study of the flare, scientists estimate the star's crust is only about a mile (1.5 km) thick. ASTRONOMY: ROEN KELLY



The goal, simply put, is to build up statistics, says Hurley. “We’d like to know the magnetar birth rate, which may be difficult to calculate if we’re limited to the magnetars in our own galaxy.”

In addition to computing the fraction of stars that turn into magnetars, researchers would like to ascertain these stars’ properties. Why does one supernova explosion lead to a magnetar, while another produces a pulsar? The question extends beyond an interest in magnetars alone. “We’re talking about the endpoint of stellar evolution,” Gaensler explains. “If you want to learn about the star cycle and understand what happens when stars die, you need to understand magnetars.”

Mass, the property that most determines a star’s destiny, is clearly an important part of the equation, but it’s not the whole story. To make a magnetar, the core of the pre-supernova progenitor star must rotate rapidly (about 1,000 times per second) at the end of its life. In Duncan and Thompson’s

picture, the core acquires its magnetism through a dynamo effect by converting rotational energy into magnetic energy.

The best current models indicate massive stars rotate more rapidly as they die than when they’re young. To wind up as a magnetar, however, the star has to shed much of its mass before it goes supernova, perhaps by expelling it in strong stellar-wind outflows. Stars with high metal content—elements heavier than helium—have stronger winds, Gaensler notes. So, in addition to looking at the masses of cluster stars, scientists should look at metal content, too. “You wouldn’t expect to find magnetars in a low-metallicity cluster,” he says.

To Thompson, the question of the source of magnetars boils down to this: “What kinds of stars end up with rapidly rotating cores?” That’s difficult to say, he notes, “since no one knows how rotation evolves in the center of a massive star.” And although astronomers can measure how fast a star’s exterior is spinning, they still

can’t correlate rotation in the outer layer with what’s going on inside.

Given the uncertainties at the theoretical end, perhaps our best recourse is to see where the observations are taking us, Woods notes. Duncan agrees: “Many details of how magnetars behave are poorly understood. To a great extent, theorists are now being led by the observations.” That’s ironic, because when he and Thompson first dreamed up magnetars, there was little evidence the objects existed.

Thompson, for his part, finds it exhilarating to track the new magnetar data now coming in. While the findings have supported some of the early views he and Duncan advanced, they also have served to underscore the many puzzles scientists must still resolve.

Fortunately, growing numbers of astronomers are now interested in taking on these challenges. Indeed, many high-energy astrophysicists regard the December 27, 2004, magnetar burst as a watershed event. It’s comparable in significance to supernova 1987A, the first naked-eye supernova in centuries and the only one from which neutrinos were detected. Recognition of this has brought more attention to magnetars.

“It’s certainly becoming more of a mainstream field, and we’re attracting talented, new people all the time,” Woods explains. “That has led to some nice new results, and it’s only going to get better.” ■

**ONLINE
EXTRA**

Come to www.astronomy.com/toc for more on SGR 1806–20’s flare.

{ LIFE IN THE UNIVERSE }

Does life really need water?

NASA's quest for life says, "Follow the water." But is that nature's only choice? /// BY STEVE NADIS

EARTH — the only known abode of life in the universe — possesses massive amounts of water. Many scientists think water would be essential to any life anywhere. NASA





TITAN — Saturn's biggest moon — has an orange-hued surface with methane lakes. Some scientists believe this liquid might be sufficient for life to get established.

ERICH KARKOSCHKA/ESA/NASA/UNIVERSITY OF ARIZONA

Water, we're told, is essential for life. It comprises 60 percent of our bodies and covers 70 percent of our planet. To have any hope of finding life elsewhere in the universe, the conventional wisdom holds, we must "Follow the water," to borrow a phrase from NASA.

Indeed, this premise underlies the space agency's multibillion-dollar effort to find and explore other worlds that might be habitable — missions that include the Mars Exploration Program, Europa Orbiter, Kepler, and Terrestrial Planet Finder, as well as European Space Agency ventures like Mars Express and Aurora.

When looking for "life as we know it," this strategy makes sense. But what about life as we don't know it — life perhaps based on different chemistries and energy sources than the hometown blend? Assuming life exists elsewhere in the cosmos, is liquid water essential for it, too? Will no substitute do other than good old H₂O? And by focusing our attention strictly on water, might we miss out on untold worlds of possibilities?

In 1973, Carl Sagan contested a claim made 60 years earlier by Harvard biochemist Lawrence Henderson that life necessarily must be based on carbon and water, and have its higher forms metabolizing free oxygen. "I personally find this conclusion



FREE-FLOWING WATER likely formed the steep-sided Nani Valles on Mars. Features like this have convinced planetary scientists that water played a key role in martian geology. ESA/DLR/FU BERLIN/G. NEUKUM

suspect,” wrote Sagan, “if only because Lawrence Henderson was made of carbon and water and metabolized free oxygen. Henderson had a vested interest.”

Princeton astronomer Christopher Chyba, a former Sagan student, also cautions against a “hydrocentric” viewpoint when contemplating life beyond Earth. Keeping an open mind, as Chyba recommends, may be the only sensible approach, given all the uncertainties. Short of finding evidence of organisms based on different biochemistries, the question — Is water necessary for life? — will be difficult, if not impossible, to resolve. We have just one example of life at the moment, and it requires water. Beyond that lies speculation: Arguing that water is necessary for life is just as speculative as arguing that life without water — based on, say, silicon and liquid nitrogen — is possible. Either way, it’s a theoretical argument.

What is life?

To make any headway on the problem, scientists need to define life (no easy task in itself) and determine the critical functions water performs to sustain it. Does another fluid possess enough of water’s vital properties to give life a chance of taking hold? If we’re lucky, the answers to some of these questions may await us on Saturn’s moon Titan. Fortunately, the Cassini spacecraft continues its surveillance of this intriguing world.

Contributing Editor **Steve Nadis** is a science writer living in Cambridge, Massachusetts. He wrote about cosmologist Henry Tye in the October issue.

But before traveling halfway across the solar system, let’s start at the beginning — with the definition of life. *Life* is notoriously hard to define. “You have to think carefully about what you mean,” warns Stanford chemist Richard Zare. “If you consider life a system that’s self-organizing and self-reproducing, then stars are alive.”

In 1994, a NASA panel defined life as a “chemical system capable of Darwinian evolution.” Life doesn’t just sit there; it does something. And that “something,” in large part, is metabolism — the process of taking in materials, extracting energy from them to fuel growth and other activities, and then expelling the waste.

Motion thus appears to be a hallmark of life: A medium of some sort is needed to transport molecules into and out of the system to support metabolism and life itself. Although this medium could, in theory, be a solid or gas, liquid solvents are the natural choice. Reactants encounter each other at much higher rates in liquids than in solids. A gas may provide some of these advantages, Chyba notes, “But life in a gas phase would face enormous difficulties keeping itself confined.” That’s because heavy molecules tend to fall out of a gas yet can stay suspended in a liquid thanks to its greater density.

The nature of the solvent dictates, to a large extent, the basic features of a living system — the temperature range within which chemical reactions proceed, the type of molecules that dissolve, and the kind of chemical interactions that can take place, explain Dirk Schulze-Makuch of Washington State University and Louis Irwin of the University of Texas at El Paso. “The total chemical makeup of the living system is a consequence of the solvent in which they occur,” they write.

Why water works

On Earth, that solvent is water — a molecule endowed with numerous desirable qualities. Its high specific heat, which means it takes a lot of energy to raise water’s temperature, shields water-borne organisms from dramatic temperature swings. Water, moreover, is liquid at comparatively high temperatures. Finally, water’s ingredients are common throughout the cosmos. Hydrogen and oxygen are the first and third most-abundant elements in the universe. On the downside, water is corrosive and reactive, attacking proteins

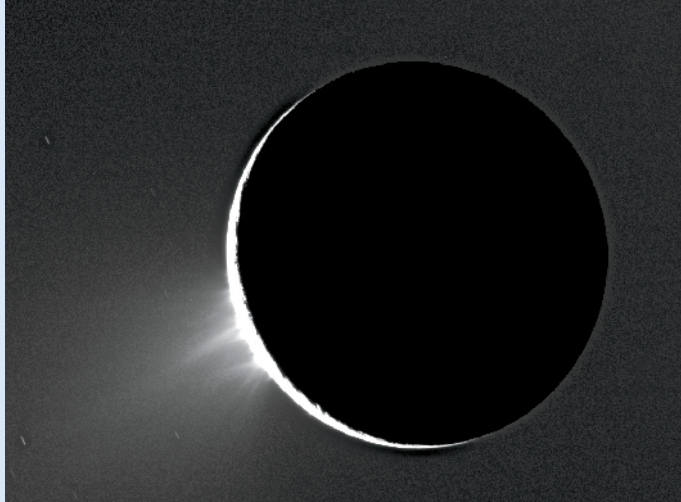
and nucleic acids. “Water-based life must therefore fight a constant battle against destruction,” Chyba says.

Life on Earth takes advantage of water’s favorable properties while coping with its deleterious ones. Although some scientists have argued water is amazingly fine-tuned to support life, others are convinced that life on Earth adapted to water rather than the other way around.

ACTIVITY SLOWS DOWN
in the absence of water,
“But if you have several
billion years to play
with, who cares?”
— Roy Daniel



EXPOSED BEDROCK in Mars’ Eagle Crater was deposited as sediments in liquid water. The Opportunity rover’s discovery of the bedrock in January 2004 proved water once pooled in this crater. NASA/JPL/CORNELL UNIVERSITY



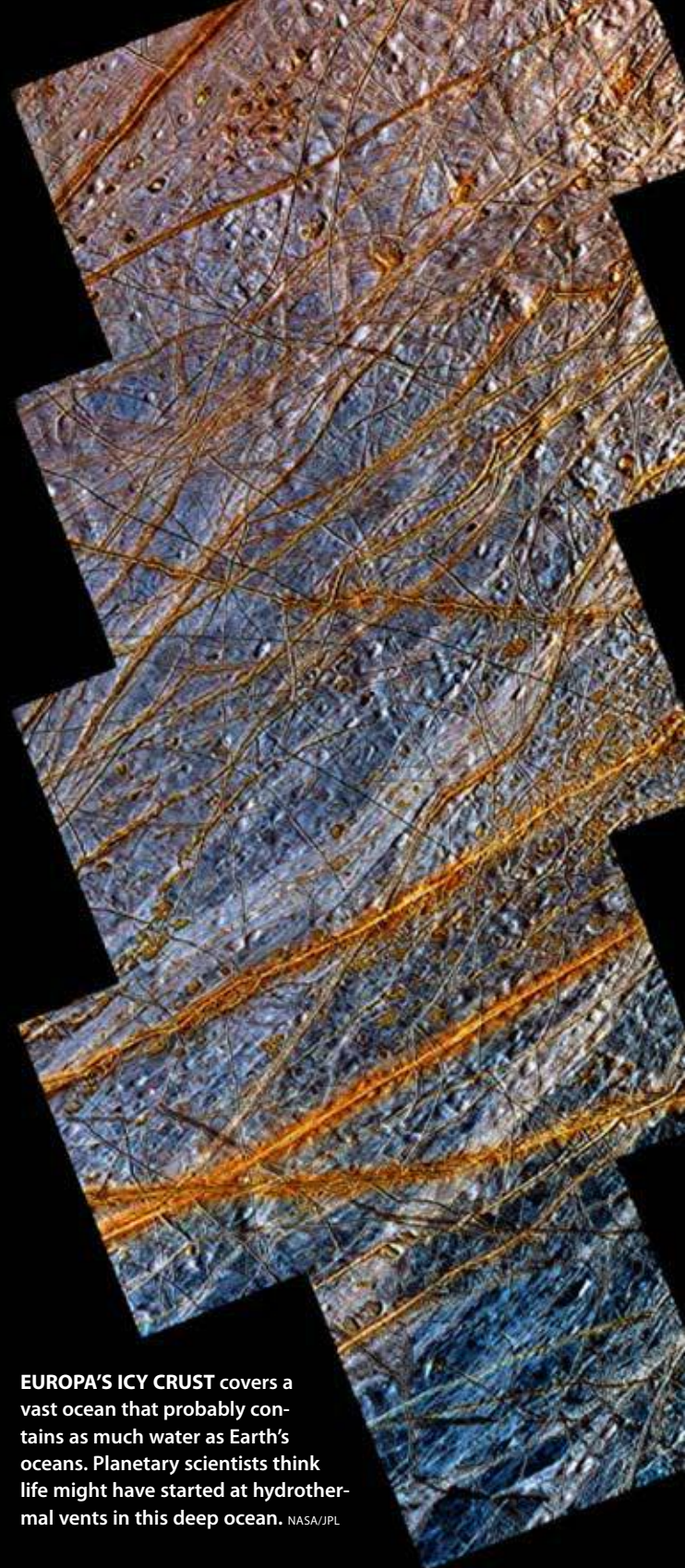
WATERY PLUMES ERUPT from Saturn's moon Enceladus. Tidal forces from the ringed planet heat the moon's interior enough that liquid water exists near the surface. NASA/JPL/SSI

No other explanation makes sense to New York University chemist Robert Shapiro. "It's pointless to look at the biomolecules we have today and marvel at how well they use water," Shapiro insists. "That's like marveling at how well the Mississippi River manages to flow under every bridge and pier. The only reasonable way to think about it is that the water was there first; life came later, evolving in ways that are compatible with it."

As for life without water, we've already gained some clues here on the so-called water planet. Some microbes and spores can survive indefinitely, it seems, in the absence of water. They persist in a dormant state, however, neither growing, reproducing, nor metabolizing. Recent experiments, meanwhile, show that enzymes also can function in little or no water. "We focus on enzymes because they are the machinery of life," explains Roy Daniel, a biochemist at the University of Waikato in New Zealand. Every biomolecule, he says, is either the target of an enzyme or the product of an enzyme, and usually both.

"Although the activity of enzymes is greatly hindered by the absence of water, there doesn't seem to be an absolute requirement for liquid water," says Daniel. Activity slows down under such conditions, "But if you have several billion years to play with, who cares?" Assuming life can function in the absence of water, as his experiments suggest, "There doesn't seem to be an obvious reason to say that life has to evolve in the presence of water."

If alternative liquids can, in principle, give rise to life, what sort of solvents should be considered? "For every interesting property of water, you can find another liquid with the same property," says University College London physicist John Finney. "But I don't think you can find one that has them all. The question is, 'How many of these properties do we need to support life?' We don't know."



EUROPA'S ICY CRUST covers a vast ocean that probably contains as much water as Earth's oceans. Planetary scientists think life might have started at hydrothermal vents in this deep ocean. NASA/JPL





CLOUD-CLOAKED VENUS contains sulfuric-acid droplets that life could use as a solvent. The acid exists with water, however, so any such life would not count as water-free. ESA/VIRTIS/INAF-IASF/OBS. DE PARIS-LESIA

Schulze-Makuch, for one, suspects life is more varied than we can imagine. “Water is the ideal solvent [for life] on Earth, but on other worlds, where temperatures and pressures are different, other solvents are more likely to be found in the liquid state,” he says.

Looking beyond water

Take liquid ammonia, which has been observed in Jupiter’s clouds and throughout the interstellar medium. At one atmosphere pressure, it exists as a liquid from -108° to -27° Fahrenheit (-78° to -33° Celsius). And, like water, it dissolves many organic compounds. In the cold environments where liquid ammonia is present, however, any biology would be slower and less dynamic than the life to which we’re accustomed. Basically, chemical reaction rates decline exponentially with temperature.

Sulfuric acid, another fluid that interests scientists, resides in Venus’ clouds. Schulze-Makuch speculates the venusian clouds may harbor life, just as microorganisms apparently have been spotted in water droplets above Europe’s Alps. Conditions 30 miles (50 kilometers) above Venus’ surface are reasonably benign, ranging between 86° and 176° F (30° and 80° C). And the lack of rain means any microorganism-bearing particles could persist in the atmosphere for months — long enough, perhaps, for scores of reproduction cycles.

A sample-return mission could determine whether unidentified particles in Venus’ atmosphere are, as Schulze-Makuch theorizes, microbes coated with an ultraviolet-protectant like sulfur. Discovering signs of life on Venus would, of course, be spectacular. Yet, because the sulfuric acid is mixed with water, this would not be an example of life without water.

Organic compounds dissolve readily in liquid hydrocarbons like methane, which appears to be abundant on Titan. However, because nucleic acids do not dissolve in such liquids, any life on Titan could

not involve DNA. One strike against methane is that it survives as a liquid only at extremely cold temperatures, from about -290° to -260° F (-180° to -160° C), thereby slowing chemical reactions to a crawl. The problem need not be fatal, claims Daniel. “I’m not sure life couldn’t proceed much more slowly in some places because what drives life to speed up is the competition. It’s possible the gold standard is much less demanding elsewhere than it is here.”

Methane’s poor solubility is harder to sidestep, contends Chris McKay of NASA’s Ames Research Center. “On Earth, life has learned to live in a rich soup. On Titan, life would have to subsist on a thin soup where organisms would work harder to get food.” Life under such circumstances would be difficult, he says, but not impossible.

University of Florida chemist Steve Benner favors the more-complex molecule formamide, which remains liquid over a wide range of temperatures and pressures. Found in dry environments like deserts on Earth and perhaps beneath Mars’ surface, “Formamide is an excellent solvent for almost anything that dissolves in water,” says Benner, yet is less reactive. Many chemicals attacked by water remain stable in formamide.

Zare considers formamide a long shot for a solvent because it is much rarer than water and more complicated: Formamide (HCONH_2) contains six atoms from four different elements, whereas water (H_2O) contains just three atoms from two elements. “I won’t say you can’t start life with formamide in the lab, but it’s not where I’d start searching,” Zare says. “You’ve got to start life with something that’s abundant.”

Others find arguments predicated on water’s abundance less persuasive. Apart from Earth, Benner says, “Liquid water is hard to find in our solar system.” Daniel agrees: “Although water is surely widespread in the universe, there aren’t as many places you see it in the liquid phase. So another liquid may be more important in some of these environments.”

All told, says University of Arizona astrophysicist Jonathan Lunine, “There are probably countless planets with liquid water, as well as planets with other liquids. In the end, we’re left with the same question: On which of these planets, and with which of these liquids, can life take hold?”

Some clues may emerge from the laboratory, where a handful of researchers are studying alternative chemistries for life. Preliminary experiments, which show organic silicon compounds are unusually

soluble in liquid nitrogen, give Cambridge University chemist William Bains hope that silicon-based (rather than carbon-based) life might be plausible.

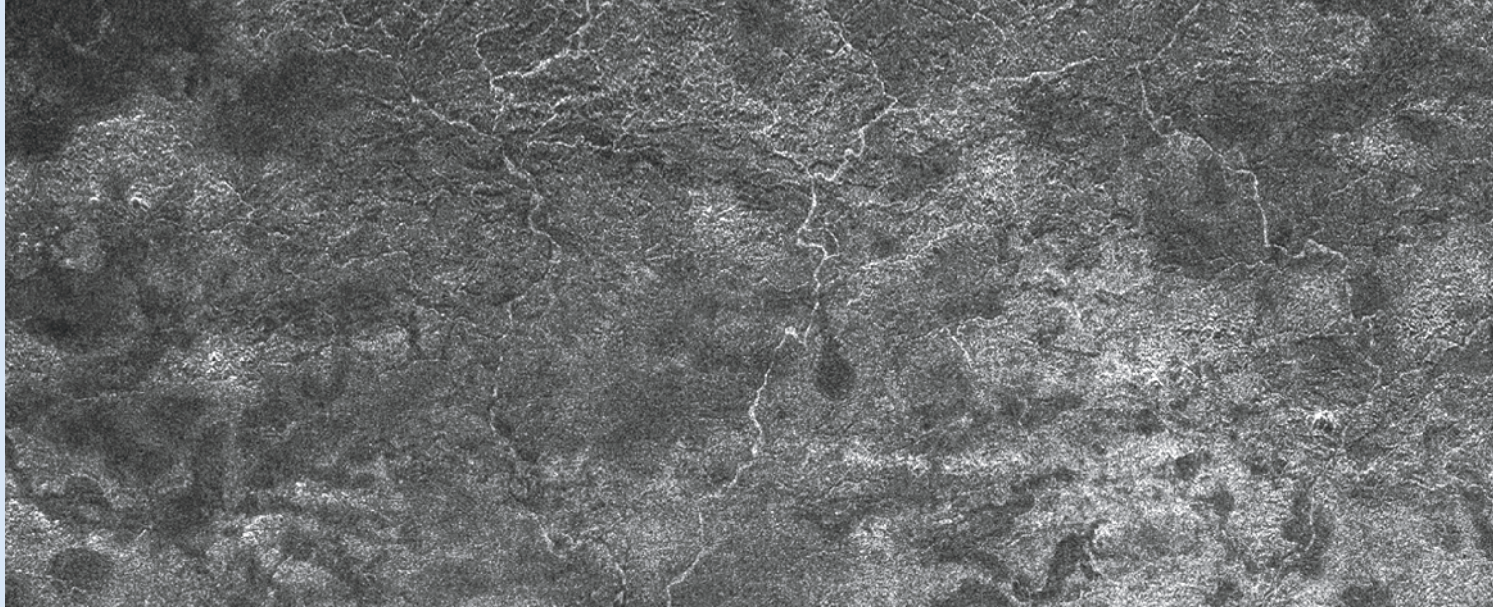
Benner, too, is investigating potential solvents in the lab. To some degree, he says, “We’ll have to rely on experiments because they’re much cheaper than space missions.” The drawback is that such experiments — designed by humans with human experiences — inevitably are limited by our imagination. “To see something really new and unexpected, we have to go out into the cosmos.”

Titan’s promise

Others agree that theoretical considerations alone cannot tell us what kinds of life exist in the universe and what kinds of liquids

“NOTHING FORBIDS
the origin of life
as we *don’t* know it,
although it could be
hard to recognize.”

— *Robert Shapiro*



SINUOUS RIVER NETWORKS cut through the hills and valleys of Xanadu — an Australia-size “continent” on Saturn’s moon Titan. Scientists think liquid methane or ethane carved these channels.

Elsewhere on Titan, the Cassini spacecraft has discovered lakes of liquid hydrocarbons. In this radar image, bright regions signify rough terrain, while dark areas are smooth. NASA/JPL

support it. “The biological uncertainties are sufficiently great that we need to rely on exploration to the extent possible,” says Chyba. For the moment, this pretty much means Titan — the only place other than Earth known to have surface liquids.

The Cassini spacecraft will have visited Titan 44 times once its primary mission wraps up in July 2008. When Cassini flew by in January 2005, it deployed the Huygens probe, which parachuted through the moon’s thick atmosphere and landed on the surface. Although Titan remains shrouded in mystery, Cassini and Huygens have uncovered signs of liquid methane or liquid ethane on the moon, as well as hints of large methane reservoirs. While there’s no evidence of life, per se, on Titan, methane’s sheer abundance makes Schulze-Makuch believe some fraction of it may be biologically produced. A Huygens investigative team headed by Hasso Niemann of NASA’s Goddard Space Flight Center concluded Titan’s methane is not of biological origin, based on the measured ratio of carbon-12 to carbon-13.

However, because the Huygens probe was never designed to detect life, Schulze-Makuch insists the question remains open. “If there’s life on Titan, it would be completely different from life on Earth, so we can’t assume the same carbon isotope ratios hold,” he argues. If anything, he adds, evidence of a meteorological cycle based on methane (like Earth’s hydrological cycle), plus the general availability of liquids, organic molecules, and potential energy sources, brightens the prospect for life on Titan.

If hints of life are to be found in other places of interest in the solar system — such as Mars, Europa, or Venus — it’s likely to be water-based. Expanding our reach through remote observations of extrasolar planets is, unfortunately, well beyond current capabili-

ties. “Right now we can barely analyze the atmospheres of the giant planets in our solar system,” says Chyba. “We’re probably decades away from being able to do that for planets around other stars.”

Where does that leave us? To Zare, there’s little to do, practically speaking, other than to follow the water. “You have to know what you’re searching for to have a reasonable chance of finding it,” he says. “Unless you narrow down the options, you’ll search for everything and wear yourself down.” Targeted searches are expensive enough, he notes. Searching for everything would bankrupt us.

Following the water ought to be a central, if not dominant, strategy. Yet, doing so to the exclusion of everything else could close ourselves off to breathtaking discoveries. “With billions of stars and probably billions of planets, there should be places where life exists in a liquid other than water,” Schulze-Makuch predicts.

The universe, Shapiro agrees, is a big place with unfathomed possibilities: “Nothing forbids the origin of life as we *don’t* know it, although it could be hard to recognize.” The only way we’ll find out about other kinds of life is to locate planets where solvents other than water are abundant and then see what, if anything, is alive in them, he adds. “If we just sit on our hands, we’ll never know.”

In the end, the question of whether water is the only liquid capable of sustaining life may be tied to an even broader

issue: Is there life elsewhere in the universe? “I consider it unlikely that we’re the only life in the universe,” Schulze-Makuch says. “It’s the same with solvents: I consider it unlikely that water is the only possible solvent, but we can’t rule it out.” And unless some still-to-be-analyzed data from Huygens reveal compelling signs of life on Titan, we’ll ponder this question for years to come. ■



TITAN’S ATMOSPHERIC HAZE results from photochemical reactions with hydrocarbon molecules like methane. The thick haze is one sign that methane gets cycled from the surface to the air and back. NASA/JPL/SSI

Making waves

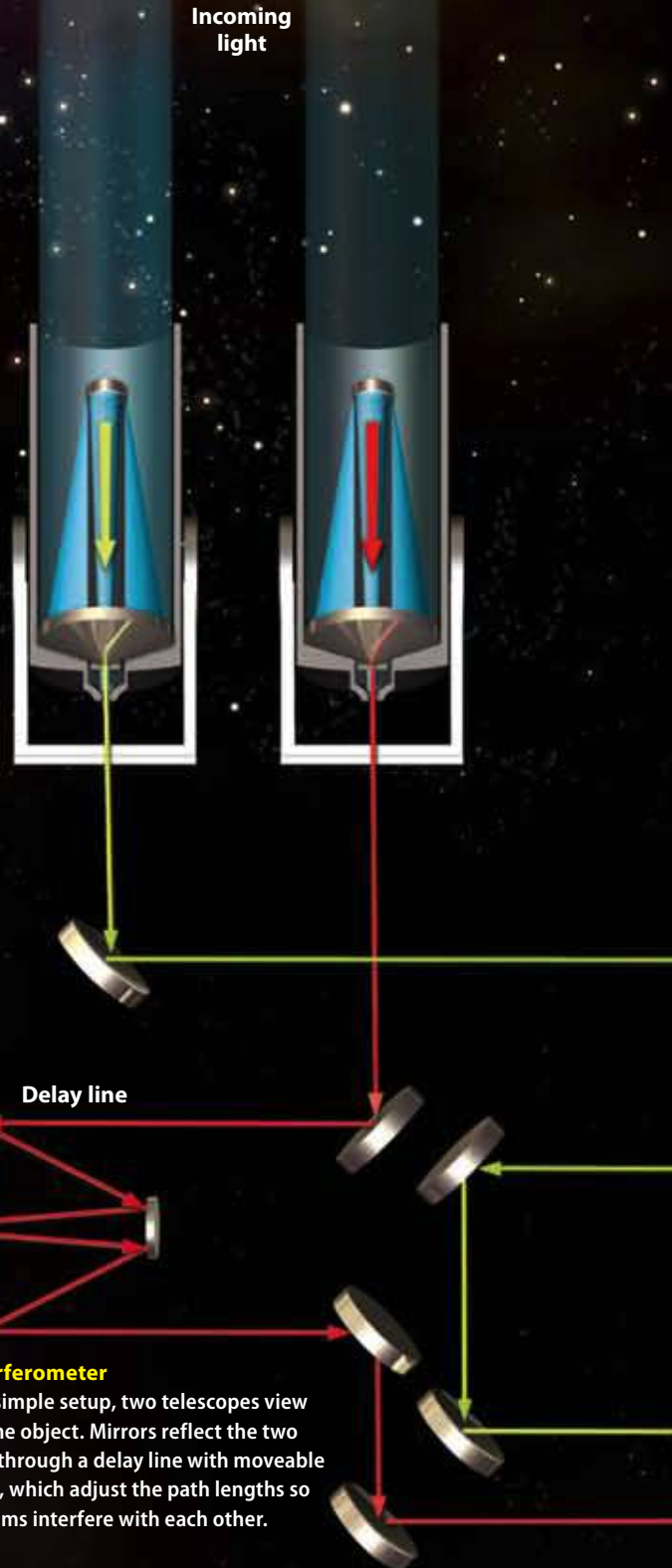
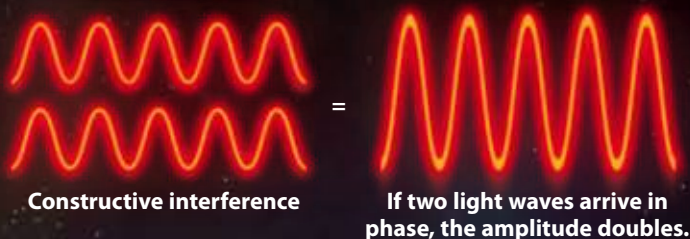
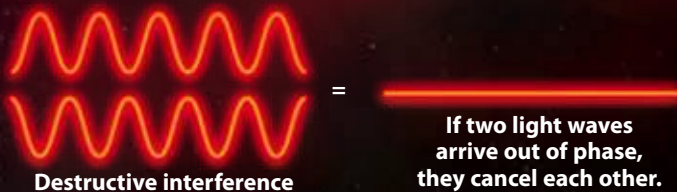
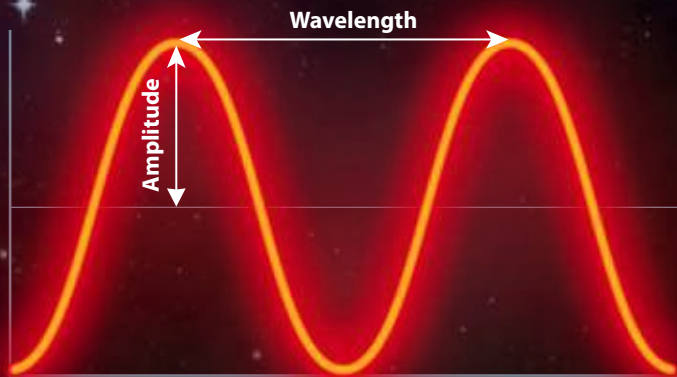
Astronomers see incredible detail with a technique called interferometry.

/// BY RICHARD TALCOTT; ILLUSTRATIONS BY ROEN KELLY

Astronomers always want to see finer detail. This is why they build bigger and better telescopes and even loft some of those scopes above Earth's distorting atmosphere.

A telescope's ability to resolve detail depends on its aperture — the diameter of its primary lens or mirror. But there's a way around this limitation: Combining light from two or more telescopes can achieve the same resolution as a single scope with a diameter equal to the scopes' separation. The technique — called interferometry — takes advantage of light's wave properties to produce ultra-sharp views.

American physicist Albert Michelson (1852–1931) invented the interferometer in 1881 to gauge the speed of light in different directions. The experiment showed a constant speed, which proved a cornerstone of Einstein's special theory of relativity. Michelson later used an interferometer to measure the angular diameter of the star Betelgeuse. Today, astronomers employ interferometry at both radio and optical wavelengths to get the sharpest views possible. ▀





NASA

▲ Terrestrial Planet Finder (TPF)

If NASA gets its way, this multi-spacecraft mission could fly in a decade or so. It will use interferometry to search for earthlike planets by canceling a parent star's light.

Wanted: two or more scopes

Interferometers come in all shapes and sizes and, one day, will exist in space. Researchers typically observe in visible light or radio waves, but the technique works with all light forms and even gravitational waves.



ESO

▲ Very Large Telescope Interferometer (VLTi)

Four 8.2-meter telescopes on the summit of Cerro Paranal in northern Chile can be used individually or together. When combined, they form the world's biggest optical interferometer, having a resolution equivalent to a 200m scope.



RICHARD WAINSCOT

▲ Keck Interferometer

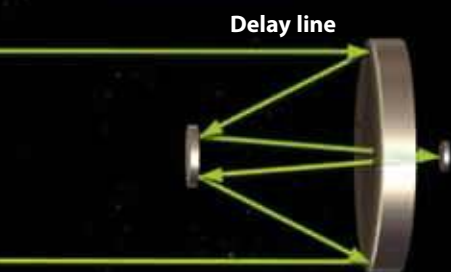
These twin 10-meter scopes reside atop Mauna Kea on the Big Island of Hawaii. When used together, they achieve the resolution of a single 85m scope.



NRAO/AUI

▲ Very Large Array (VLA)

These 27 radio antennae near Socorro, New Mexico, give remarkable views of the radio sky.



Delay line

Detector

▼ Interferometric fringes

The detector combines the two beams, producing alternating bands of light and dark called fringes. Astronomers analyze the fringes to reconstruct a highly detailed image.



ASK ASTRO

Astronomy's editors and experts from around the globe answer your questions about the cosmos. This month: Light's speed depends on the material it travels in, and the Moon's path is explained.

FASTER THAN LIGHT?

Q: In "Who knows what dangers lurk in space?" (March 2006), you stated, "Cerenkov radiation occurs when certain high-energy particles move through water or the atmosphere faster than the speed of light." How can anything exceed the speed of light? — LOIS McLATCHIE,

MAYFIELD HEIGHTS, OHIO; AND JOHN BENBOW,
NATIONAL CITY, CALIFORNIA

A: The familiar claim, "Nothing can go faster than light," is, in fact, misleading. **Light travels at different speeds in different media.** The speed depends on the medium's index of refraction (n). Light moves fastest in a vacuum — the symbol c refers to this speed of 670,616,629 mph (1,079,252,849 kilometers per hour, or

299,792,458 meters per second). We write the speed of light in any other medium as c/n .

Vacuum has an index of refraction of 1.0; therefore, light's speed in a vacuum is c . But light traveling in water — which has an index of refraction of 1.33 — moves at only $c/1.33$, which equals $0.75c$, or 75 percent of its speed in a vacuum.

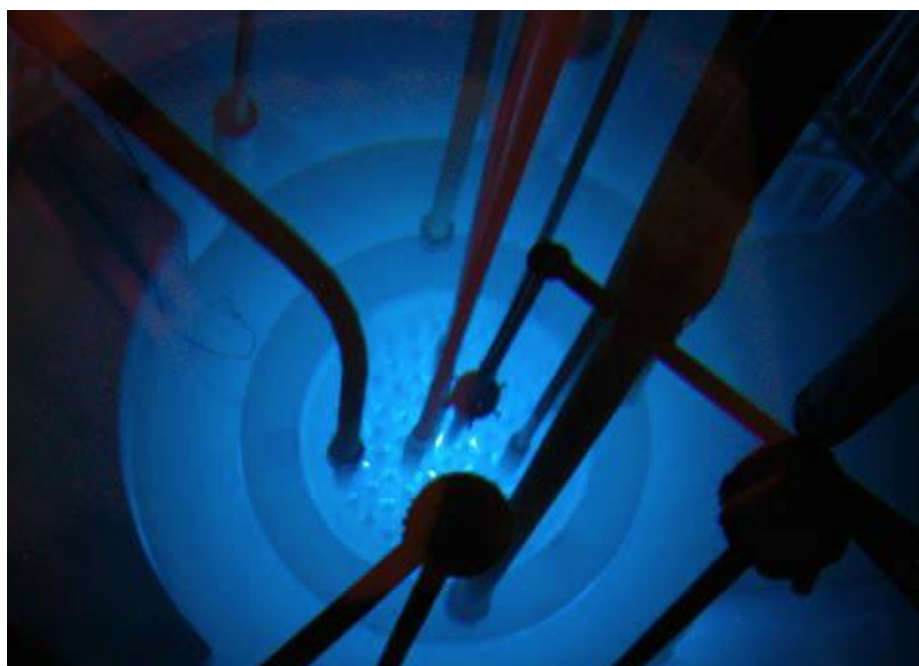
Most types of glass have indices of refraction between 1.5 and 1.6. So, light traveling in a glass lens moves 60 to 67 percent as fast as it does in a vacuum.

Light changes speed immediately when it passes from one material to another. This is because light interacts with the electric fields of atoms in the material. In fact, this difference is what causes light to change direction, or refract. This is what makes, among other things, telescope lenses possible. Given that the index of refraction is always greater than or equal to 1.0, we can

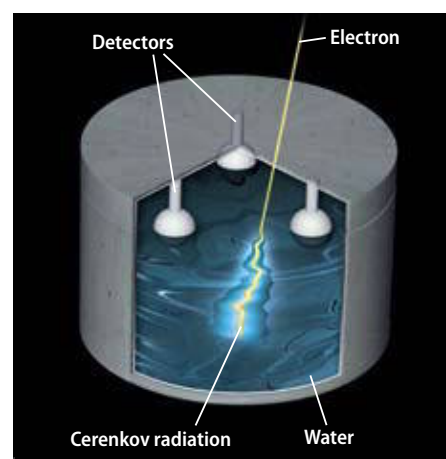
now make a more accurate statement about cosmic speed limits: Nothing can go faster than light in a vacuum.

Objects, however, are free to move at any speed, although objects with mass can never reach c — the speed of light in a vacuum. Special relativity tells us it takes progressively more energy to accelerate an object closer and closer to c . Actually getting to c would require infinite energy.

Consider a high-energy particle produced in an air shower — when a cosmic ray collides with an atom in the atmosphere. Let's say it's moving at about 86 percent of c . In air, where the index of refraction is 1.0003, light travels at 99.97 percent of c , so it easily outruns the incoming particle. But, when the particle enters a tank of water, it continues to move at 86 percent of c , while light itself slows to only 75 percent of its vacuum speed. The



CERENKOV RADIATION appears as a blue glow in water surrounding a nuclear reactor's core at Kansas State University. K-STATE TRIGA MARK II NUCLEAR RESEARCH REACTOR



ASTRONOMY: ROEN KELLY

A FAST-MOVING ELECTRON remains at a constant speed as it moves from one medium to another. But light (electromagnetic radiation) travels slower in water — at 75 percent of its vacuum speed. The passing electron disrupts electrons around water near it. Once the particle passes, these electrons emit light as they return to their previous state.

particle exceeds the local speed of light in the water.

An interesting thing happens when the high-energy particle carries an electric charge. The particle's electric field propagates slower in water than the particle itself. The result is Cerenkov light.

The details of the Cerenkov process are complicated, but the example of a sonic boom captures most of the features. A sonic boom occurs when an airplane travels through the air faster than the speed of sound. As a result, the airplane "outruns" the noise it is producing, and all the sound piles up behind it into a single coherent wave front called a sonic boom.

With Cerenkov radiation, the "noise" is the presence of an electric field, and the sonic boom is a burst of blue light. — SCOTT WAKELY, UNIVERSITY OF CHICAGO

MOON CHASE SUN

Q: Does the Moon follow the same path across the sky as the Sun? — MICHAEL MCCOY, OCALA, FLORIDA

IN THE KNOW

ECLIPTIC

The plane of Earth's orbit around the Sun; therefore, from our viewpoint on Earth, also the Sun's apparent path across the sky.

LUNAR NODES

The points where the Moon's orbit crosses the ecliptic.

LUNATION

The average time for one lunar cycle, roughly 29.5 days.

INDEX OF REFRACTION

A material's characteristic that determines what speed light travels in that material; the higher the number, the slower light will propagate through the medium.

VACUUM

A volume of space devoid of matter; or where gaseous pressure is much less than atmospheric pressure.



THE FULL MOON always rises in the eastern sky, but the exact rising point varies throughout the year. It rises north of due east in summer and south of due east in winter. The Full Moon rises farthest north and south every 18.6 years. Here, it rises over Sounion, Greece.

A: As Earth orbits the Sun each year, the Sun appears to cross in front of more than a dozen constellations. As observers on a nearly circular path that takes 365 days to complete, we find the Sun moves approximately 1° per day against the background stars. This movement defines a line, called the ecliptic, around the celestial sphere. The ecliptic is inclined 23.5° to the celestial equator because this is the amount Earth's rotation axis is tilted relative to its orbit.

The Moon follows generally the same path, but with some important differences. The Moon's orbit is tilted 5.1° relative to the ecliptic. So, **the Moon can appear anywhere in a band extending 5.1° north (above) and south (below) of the ecliptic.**

Each month, the Moon twice crosses the ecliptic on opposite sides of Earth. These intersections are called the nodes of the Moon's orbit.

The nodal points also wander along the ecliptic. An imaginary line connecting the nodes through Earth's center rotates around the planet every 18.6 years. When the Moon lies on a node, Earth, the Sun, and the Moon lie in the same plane. Rarely do the nodes line up exactly, but when they do — and if the Moon happens to be at new or full phase — total solar or lunar eclipses occur. However, due to the 5.1° tilt, eclipses do not occur every month. The 18.6-year period is called the Saros cycle, and it is used to help determine the periodic repetition of eclipses.

One result of the Moon's orbital tilt is that when the Moon's orbit is oriented such that it passes farthest north of the ecliptic in Gemini — which is the northernmost point of the ecliptic — the Moon stands

much higher in the sky than usual. At the opposite side of the sky during the same lunar cycle — roughly 29.5 days — the Moon lies farthest south of the ecliptic; on these occasions, the Moon appears lowest in our sky. Such extremes are reflected also in the Moon's rising and setting points, which then occur farther north and south than usual.

The Moon's rising and setting points wander back and forth between the extremes, but not over an annual cycle like the Sun. Instead, the Moon performs this cycle every month (overlaid on a slow 18.6-year cycle as well), and with a swing relative to the Sun that can reach plus or minus 5.1° . When the line of nodes aligns with the solstices, the tilt of the Moon's orbit causes the Moon to pass either 5.1° above or below the ecliptic at the nodes' northern and southern extremes.

Such a configuration, referred to as the Major Lunar Standstill, occurs this year. The Moon's declination varies across its widest possible range, from 28.8° above and below the celestial equator. The rising and setting points are at these extremes for a number of months. During the next few years, the Moon's rising and setting points will wander back toward matching the Sun's locations. These lunar rising and setting points will equal those of the Sun once the lunar orbit's line of nodes is aligned with the equinoxes.

— MARTIN RATCLIFFE, A FORMER PRESIDENT OF THE INTERNATIONAL PLANETARIUM SOCIETY

Send your questions to: askastro@astronomy.com; or write to: Ask Astro, P. O. Box 1612, Waukesha, WI 53187. Be sure to tell us your full name and where you live. Unfortunately, we cannot answer all questions submitted.

NOVEMBER 06

Mercury's solar excursion

A rare astronomical treat awaits observers

November 8. Starting at approximately 2:12 P.M. EST (11:12 A.M. PST), Mercury's black disk begins a 5-hour trek across the Sun's face. The planet's leisurely pace allows plenty of time to appreciate solar system dynamics. And the transit provides a great opportunity to

share your expertise and telescope with others.

The transit is strictly a telescope event. As with any Sun observation, you must project the Sun's image or use a safe solar filter to avoid damaging your eyes and equipment.

The Sun sets before Mercury finishes its transit for all the Americas except along the West Coast. (The planet completes its passage at about 4:10 P.M. PST.) On the plus side, this means we might see some colorful visual effects as the Sun and Mercury set through Earth's turbulent lower atmosphere.

The next Mercury transit doesn't come until 2016, so it's worth heading to clear skies if the weather looks iffy.

Speaking of the weather, November ranks as the cloudiest month of the year for many places in mid- and northern latitudes. The culprit: cold air sweeping over warm, open water. That makes this a good month for telescope maintenance, winterizing, and planning observing sessions. If you own a Newtonian reflector, grab a cup of coffee and prac-



MERCURY'S TINY, PITCH-BLACK DISK grazed the Sun's limb during this 1999 transit. Mercury tracks closer to the Sun's center during this month's transit. LEE C. COOMBS

tice aligning (collimating) the optics. The experience will help you do it faster when you're in the field. You'll be amazed at the detail you can see when the scope's mirrors are just right.

Saturn rises late this month, cresting the eastern horizon near 11 P.M. Unfortunately, this means crisp, steady images won't be likely until near dawn, when the ringed planet rides high in the south. On a steady morning, you should be able to

spot the planet's shadow falling on the rings and the Cassini Division; with a 6-inch or larger scope, the inner Crepe ring and delicate cloud bands in Saturn's atmosphere also appear.

During November's first week, the Full Moon reveals more of its south polar area than usual. In addition to seeing "past" the pole to glimpse a bit of the lunar farside, we get a nice 3-D effect as shadows exaggerate vertical depth. Nor-

mally, a Full Moon looks flat because these shadows are hidden from view.

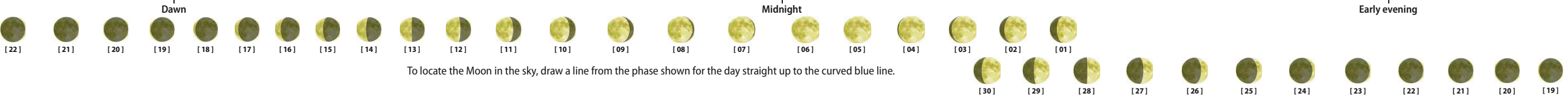
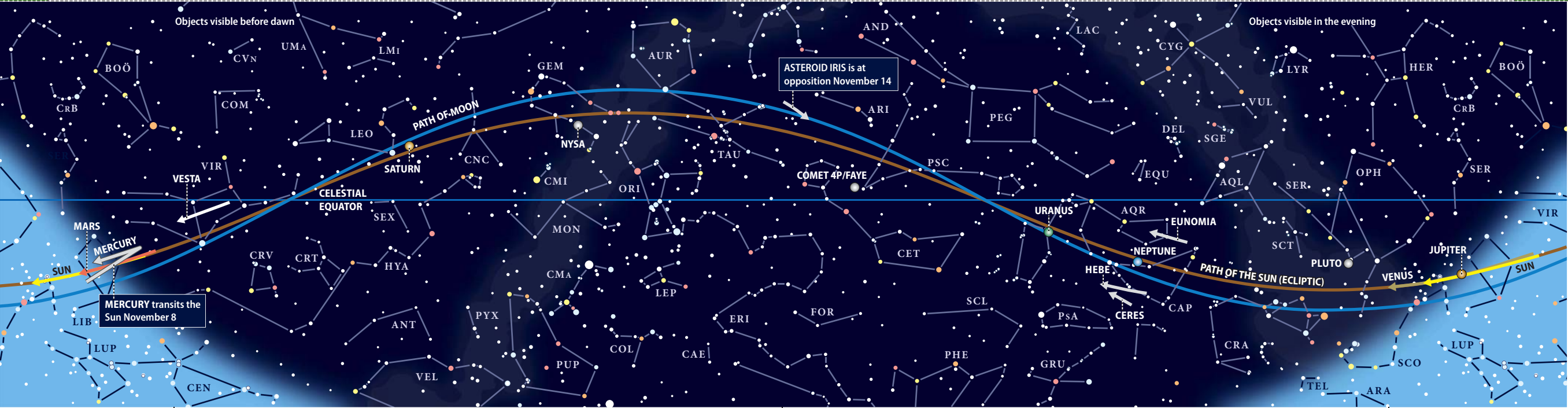
If you do most of your observing in the evening, try using binoculars to track down the slow-moving asteroid 7 Iris, which lies near the sparkling Pleiades star cluster (M45). Also visible through binoculars, above Polaris in the north, is the yellow variable star ϵ Cephei, which is nearing the peak of its 13-month cycle.

The annual Leonid meteor shower favors night owls. As Earth sweeps through cometary debris, the heat of atmospheric entry makes these dust motes flare into incandescence as "shooting stars." Don't expect to see as many meteors as August's famous Perseid shower produces, but the swiftness of an occasional Leonid and the bright color of the more stately Taurids help make up for lack of numbers.

Finally, astronomical early birds will be rewarded at dawn with Mercury's best apparition of the year. Only a week after its transit, the innermost planet pierces the dawn glow. Scan the eastern horizon with binoculars around 6 A.M., and look for a peach-colored dot. Just 4 days later, Mercury has brightened by a magnitude and appears easily to the unaided eye. The waning crescent Moon adds a nice touch November 18 and 19.

Planets this month

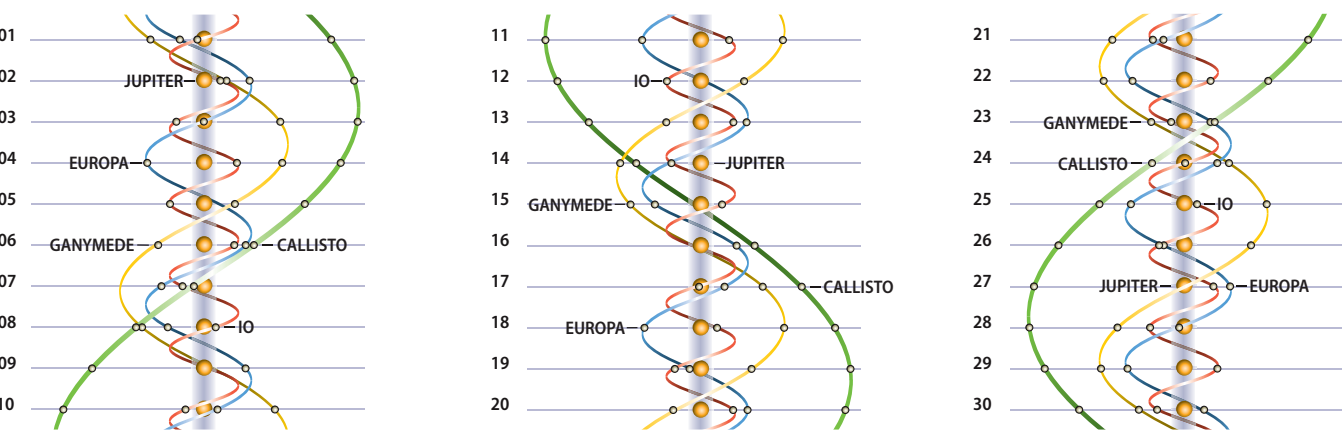
This map unfolds the entire night sky from sunset (at right) until sunrise (at left). Arrows and colored dots show motions and locations of solar system objects during the month.



PLANETS	MERCURY	MERCURY	VENUS	MARS	JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
Date	November 15	November 30	November 15	November 15	November 1	November 15	November 15	November 15	November 15
Magnitude	—	−0.7	−3.8	1.6	−1.7	0.5	5.8	7.9	14.0
Angular size	9.0"	6.1"	9.8"	3.7"	31.2"	18.2"	3.6"	2.3"	0.1"
Illumination	14%	74%	100%	100%	100%	100%	100%	100%	100%
Distance (AU) from Earth	0.747	1.108	1.707	2.550	6.326	9.152	19.753	30.128	32.018
Distance (AU) from Sun	0.308	0.370	0.725	1.574	5.382	9.168	20.086	30.051	31.198
Right ascension (2000.0)	14h32.0m	15h06.2m	15h39.1m	14h50.8m	15h30.5m	9h48.9m	22h50.0m	21h18.1m	17h40.3m
Declination (2000.0)	−13°03'	−15°20'	−19°09'	−16°12'	−18°14'	14°19'	−8°16'	−15°57'	−16°23'

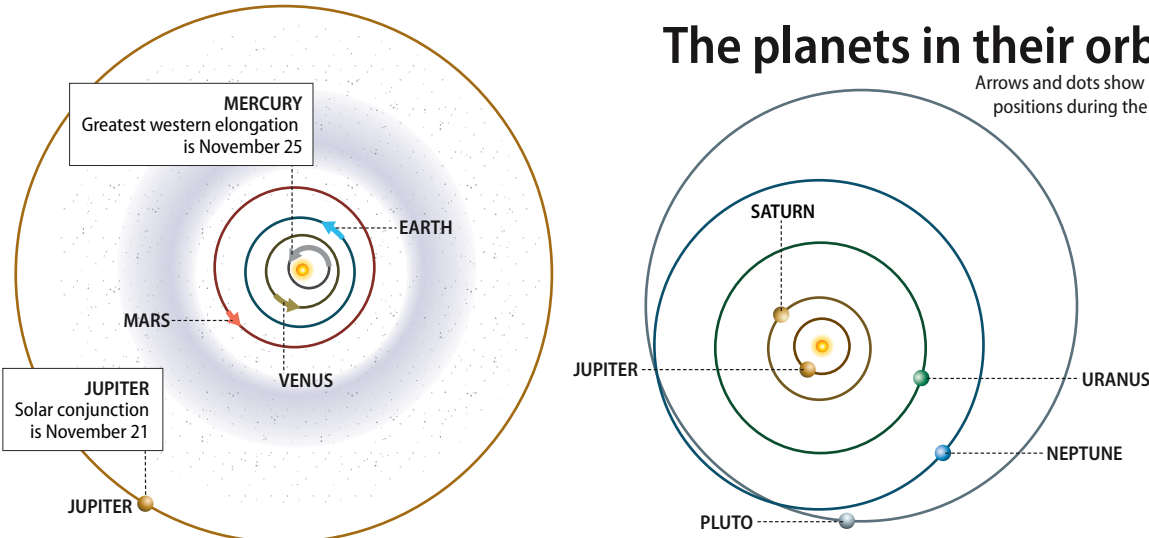
Jupiter's moons

Dots display positions of Galilean satellites at 7 P.M. EST on date shown. South is at top to match the view through a telescope.



The planets in their orbits

Arrows and dots show planets' positions during the month.



E

E



	Sirius		Open cluster
	0.0		Globular cluster
	1.0		Diffuse nebula
	2.0		Planetary nebula
	3.0		
	4.0		Galaxy
	5.0		

This map portrays the sky as seen near 35° north latitude at times shown in the upper left corner of the page. Located just outside the map are the four directions: north, south, east, and west. To

W

ILLUSTRATIONS BY ASTRONOMY-BOEN KELLY

- ONLINE EXTRA** For definitions of terms, visit www.astronomy.com/glossary.

The map shows stars' true colors, which depend on surface temperature. Hot stars glow blue; slightly cooler ones, white; intermediate stars (like the Sun), yellow; followed by orange and, ultimately, red. Fainter stars can't excite our eyes' color receptors, and so appear white unless magnified.

THE DEEP SKY

Listen to a stellar heartbeat

Cresting high in the northern sky above Polaris, Cepheus the King hangs upside down from his throne. Most people don't see the throne, but, instead, a child's simple sketch of a house. Look for a square with a triangle on top, inverted with its peak pointing to Polaris.

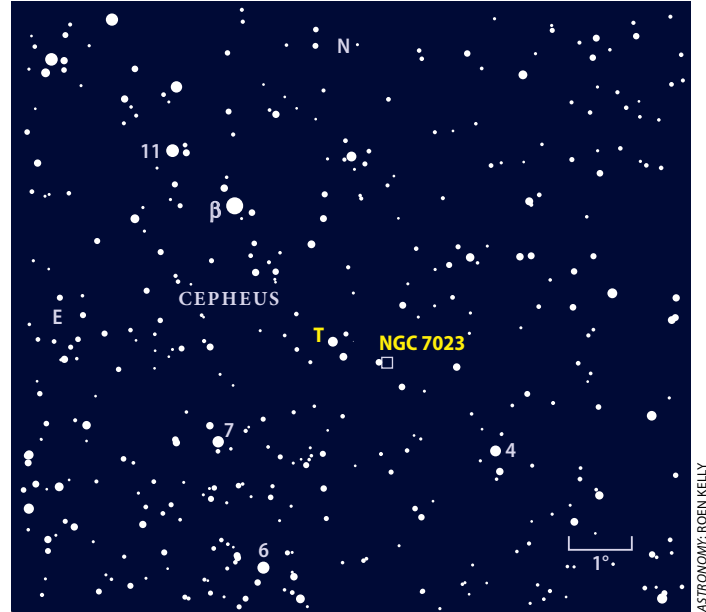
As constant as the stars appear, some galactic citizens grow and shrink with a fairly steady pulse of several hundred days. Astronomers predict the Mira variable star T Cephei will reach a maximum brightness around 6th magnitude this month. Through binoculars from a suburban backyard, T Cep then will shine with a noticeable yellow sheen. Over the next several months, it will fade to an orangish 10th-magnitude object.

The American Association of Variable Star Observers (AAVSO) would like to know your estimates of T Cephei's brightness because no one

knows whether T Cep will crest closer to magnitude 5.5 or 6.5. You can download a free comparison star chart from the AAVSO's web site (aavso.org). Click "Find charts" at upper left, type in "T Cep," and hit "go." You'll want to print out the "A" chart for binocular use. Then head outside, and in 10 or 15 minutes, you can estimate T Cep's brightness relative to nearby stars.

On the charts, comparison stars have numbers beside them: their magnitude with the decimal point omitted to avoid confusion with a faint star. Find one star a bit brighter than T and another slightly fainter, then figure where T fits on the scale between the two.

You might be surprised at how relaxing this activity is. Not only do you get to see the universe as a dynamic entity, but concentrating on the stars also has a wonderful way of sweeping aside life's irritants.



THE LONG, SLOW BRIGHTNESS CLIMB
of the Mira variable star T Cephei should culminate this month. Once you observe it, head 1° west to the Iris Nebula (NGC 7023).

Iris the nebula

Not to be confused with Iris the asteroid, a gas cloud with the same name lies just 1° west of T Cephei. You'll need a 6-inch telescope to see the glow surrounding a 7th-magnitude star. Technically speaking, the region of gas and dust scatters the star's light toward us, but we call such clouds "reflection nebulae."

Discovered by astronomer William Herschel October 18, 1793, the Iris Nebula later was cataloged as NGC 7023.

Even if your telescope's optics are dusty and produce halos around bright stars, you'll notice the difference between the Iris' glow and that of nearby stars of similar brightness. Unfortunately, higher power

and bigger scopes won't resolve the subtle details and curves visible in long-exposure images.

Hebe passes M30

If you enjoy targeting globular star clusters, you'll eventually visit M30 in southeastern Capricornus. As a freebie this month, the asteroid 6 Hebe glides past the granular globular. Hebe floats about 30' (the apparent diameter of the Moon) north of M30 the evenings of November 18–21. Only one or two field stars equal Hebe's brightness of magnitude 9.7.

Martin Ratcliffe is the former president of the International Planetarium Society. **Alister Ling** is a meteorologist for Environment Canada.



THE IRIS NEBULA'S BLUE GLOW ARISES
as dust scatters light from an embedded 7th-magnitude star. This hot star radiates mostly blue light. GEORGE GREANEY

THE PLANETS

Mercury stays in the spotlight

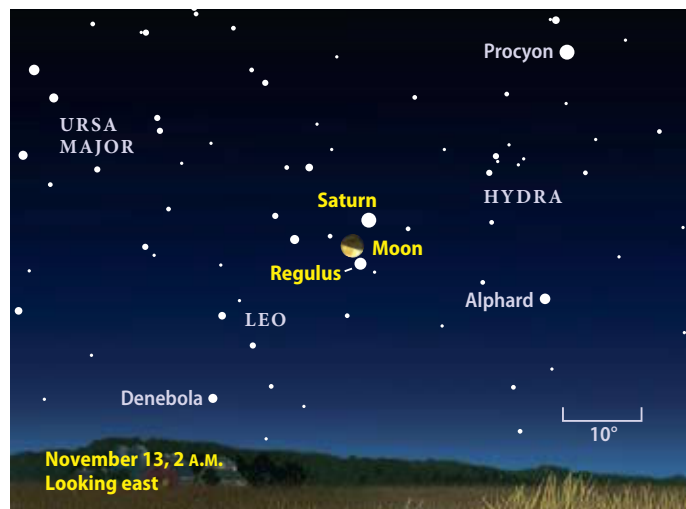
Mercury skips from evening to morning sky this month and, in the process, performs a rare transit of the Sun visible from most of the United States. This Mercury transit, the last for a decade, highlights November's planetary action. For those who prefer to observe in the dark, the evening sky nicely displays Uranus and Neptune, while Saturn appears best before dawn. Near the end of the month, Mercury returns to view in the morning sky for a fine performance.

On November 8, **Mercury** passes directly between the Sun and Earth, which produces a transit. Mercury appears as a tiny black dot as it crosses, or transits, the Sun's face over the course of about 5 hours. Much or all of the transit can be viewed from the United States, Canada, Mexico, and South America. Make the most of this

event — the next Mercury transit won't come for 10 years.

Mercury appears small enough that you'll need a telescope to spot it. Take great care when observing the transit because, as on every day of the year, the intensity of direct sunlight can damage your eyes in an instant. The safest viewing methods are to project the Sun's image onto a white card or to place a solar filter over the front of your scope. Make sure the filter is marked clearly with a safety label signifying its suitability for viewing the Sun.

The first bite of Mercury appears on the solar disk's edge at 2:12 P.M. EST (11:12 A.M. PST). This moment is called "first contact," and it signifies the transit's start. People throughout North and South America and in Hawaii will witness this stage. About 2 minutes later, Mercury's entire disk



ASTRONOMY: ROEN KELLY

SATURN AND REGULUS REMAIN A PAIR

all month, rising around midnight and climbing high in the southeast by dawn. On November 13, the Moon makes the duo a trio.

appears against the Sun's face — second contact. Over the following 4 hours and 54 minutes, Mercury's dark silhouette traverses the Sun's southern hemisphere. At Mercury's distance of 63 million miles from Earth, the planet's 3,000-mile-wide disk spans a mere 10".

Mercury reaches the midpoint of the transit at 4:41 P.M. EST (1:41 P.M. PST), and the Sun sets soon after along the U.S. eastern seaboard.

The transit's end will be visible only from west of the Rocky Mountains. Third contact occurs at 4:08 P.M. PST, followed 2 minutes later by the transit's conclusion. Residents of Hawaii and New Zealand can see the entire event. The transit's final stages can be viewed from Australia, Japan, and eastern Asia, where the Sun rises with the transit in progress.

Mercury transits can occur only in May or November, when the planet crosses the ecliptic plane. And they happen rarely — 13 or 14 times per century. The next Mercury transit occurs May 9, 2016. For more details, see "Mercury crosses the Sun" on page 80.

Neptune stands high in the south as soon as darkness falls this month. It lies in northern Capricornus, a faint grouping just east of the splashy setting constellation Sagittarius. Neptune glows at magnitude 7.9, bringing it within range of binoculars. It's much easier to see, however, if you mount the binoculars on a tripod or use a small telescope. Try to catch a view soon after darkness falls because Neptune becomes harder to see as its altitude declines. The distant planet sets by midnight.



GAS GIANTS URANUS AND NEPTUNE

remain near each other this month. Neptune lies in Capricornus, while Uranus is one constellation east, in Aquarius. ASTRONOMY: ROEN KELLY

The star chart on page 54 shows the stars Iota (ι) and 29 Capricorni. Neptune lies midway between this pair. Swing a scope toward Neptune, and you'll spy its tiny, 2.3"-diameter disk. Look carefully, and you should see subtle differences in its appearance relative to stellar images. Neptune's steadier, non-twinkling radiance and its blue-gray color give away its planetary status.

In the southern half of the sky during the early evening, the 1st-magnitude star Fomalhaut shines brightly. High above it, halfway to the Great Square of Pegasus, **Uranus** lurks near the 3.7-magnitude star Lambda (λ) Aquarii. This star will be easy to spot, and 5.8-magnitude Uranus lies less than 1° southwest of it.

A small telescope will show Uranus' 3.6"-diameter, blue-green disk. Unfortunately, the planet's elusive atmospheric details are seldom seen from the ground by optical observers. Uranus sets shortly after midnight in mid-November.

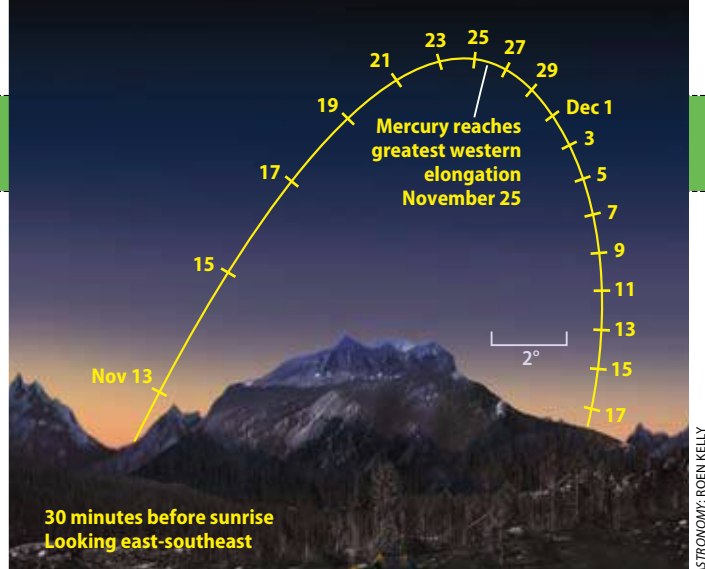
As Uranus sets in the west, look to the opposite horizon to find **Saturn** rising. Located in Leo the Lion this month, Saturn introduces a new appearance to

the well-known sickle asterism. The planet lies 5° northwest of Leo's 1st-magnitude star, Regulus, and shines at magnitude 0.5, about twice as bright as its stellar companion.

On the morning of November 13, American observers will find a waning crescent Moon approximately 2° north of Regulus. This meeting creates a wonderful trio of objects rising around midnight local time.

By dawn, the ringed planet has climbed high in the southeast, a good time for telescopic viewing. Saturn's rings now tilt 12° to our line of sight, providing magnificent views of their sunlit southern side. The two main rings, the outer A ring and the brighter B ring, can be seen through most scopes. On nights with good seeing, the faint inner Crepe ring, or C ring, also appears through 6-inch or larger telescopes. The Cassini Division that separates rings A and B shows up best at the rings' far ends.

Try to spot the shadow of the planet's disk as it falls on the rings' western side. This shadow shrinks as Saturn approaches opposition in February, and it switches to the rings' eastern side after opposition.



MERCURY'S BEST APPARITION OF 2006

comes in late November. The innermost planet reaches a peak elevation of 12° half an hour before sunrise.

Although Saturn's disk looks relatively bland, the bright equatorial zone alongside the neighboring, and slightly darker, south equatorial belt usually can be seen under good conditions. You also can track Saturn's numerous moons as they circle the giant planet. The brightest, Titan, orbits in 16 days and glows at magnitude 8.4. You'll find it due north of Saturn the mornings of November 1 and 17, and due south of the planet the mornings of November 9 and 25.

Spotting the planet's inner moons proves more challenging thanks to their relative faintness and proximity to Saturn's glare. Mimas lies closest to Saturn of the major moons. It glows at magnitude 12.8 and lies only 1.5 planet-diameters away from Saturn's center. Enceladus lies about 2 planet-diameters away and glows a little brighter, at magnitude 11.8.

Other moons are easier to spot. In order of increasing distance from Saturn, they are Tethys (magnitude 10.3), Dione (magnitude 10.4), and Rhea (magnitude 9.7). At their greatest elongations from Saturn, these moons lie 2.5, 3.1, and 4.4 planet-diameters from Saturn's center, respectively. Elsewhere

in their orbits, they appear closer to the planet.

Mercury leaps into the morning sky following its November 8 transit of the Sun. On November 18, the planet lies 11° to the lower left of a slim crescent Moon. The following morning, the pair stands only 7° apart, but the Moon lies lower than Mercury in the brightening twilight and is harder to spot. Mercury brightens with each passing day, reaching magnitude -0.2 November 20.

The innermost planet arrives at greatest elongation November 25, when it stands 20° west of the Sun. Shining at magnitude -0.5, Mercury appears impressive in the eastern sky before dawn. The planet rises 100 minutes before the Sun and clearly outshines the 1st-magnitude star Spica in Virgo, which then lies higher in the southeast. Mercury remains on view through the end of the month, brightening slightly to magnitude -0.7.

Venus, Mars, and Jupiter all lie too close to the Sun for viewing this month. But mark your calendar for early December, when Mars and Jupiter have a spectacular morning conjunction with Mercury.

Saturn on November 24, 4 A.M. EST



SATURN'S MOONS DANCE THEIR WAY

around the planet and create constantly changing patterns.

November 24 finds six moons west of Saturn. ASTRONOMY: ROEN KELLY

METEORS AND MOONS

Hot meteors for cool nights

The Leonid meteor shower has lost some of its mystery but none of its charm over the past several years. Thanks in large part to the work of David Asher of Armagh Observatory in Northern Ireland and Robert McNaught of the Australian National University, the past few years have seen a dramatic increase in our understanding of this shower. They successfully predicted major Leonid storms by calculating Earth's passage through trails of debris left behind during previous returns of the shower's parent comet, 55P/Tempel-Tuttle.

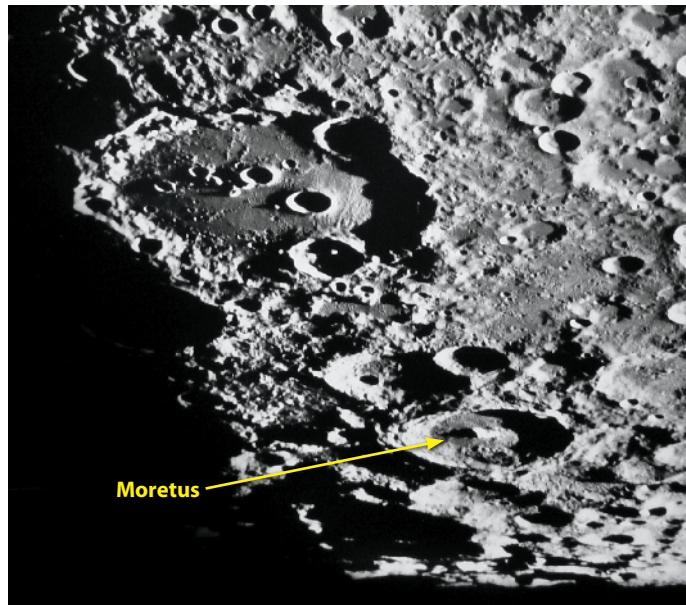
This year, Earth passes through a debris trail left by the comet's 1932 passage, and a brief, sharp increase in meteor counts should occur. Astronomers expect meteor rates to reach about 100 per hour around 4h45m UT November 19 (11:45 P.M. EST on the 18th).

This timing favors observers in Europe and Africa.

The Leonids' traditional peak — when Earth passes through the plane of Tempel-Tuttle's orbit — is November 17. This peak should bring about one meteor every 3 minutes, on average. Combined with the brief increase expected November 19, a broad window of 3 mornings should offer good Leonid viewing. The waning crescent Moon makes conditions close to perfect, and all the more attractive, for meteor watching in the predawn sky.

On to the pole

The Moon's northerly declination around the November 5 Full Moon offers observers a fine chance to view the Moon's southern polar region under full illumination. The large crater Clavius will appear more rounded than usual; and closer



FROM CONSOLIDATED LUNAR ATLAS (LPL/JAA)

TERRACED WALLS AND A CENTRAL PEAK

highlight lunar crater Moretus. November's Full Moon offers a good opportunity to explore this region near the Moon's south pole.

to the pole, you'll get a good look at Moretus.

Moretus is a magnificent 71-mile-wide crater with a central mountain peak towering 1.5-miles high. The crater's terraced walls remind some observers of the better known crater Tycho, located farther north. The Moon's zero longitude runs tangent to Moretus' eastern wall.

Searching farther south, toward the pole, is a challenge because the craters all appear foreshortened. Moving from Moretus toward the limb, the next crater you'll encounter is Short, a 44-mile-wide impact scar. Short shares its southwestern wall with a slightly larger crater, Newton.

Southeast of these two craters lies the complex region of the southern pole. The Leibnitz Mountains stretch across the region, although they actually form part of the rim of a huge depression that sinks 5 miles below the Moon's average radius. If conditions are just right, you might spy the crater Shackleton, named after the famous British polar explorer. It lies at the Moon's south pole. The Clementine spacecraft detected evidence of ice inside this crater, in a region that remains in perpetual shadow.

When the Moon reaches full phase November 5, you'll find that a lunar filter will cut the glare, allowing careful study of this fascinating region.



A BRIGHT LEONID METEOR STREAKS

below brilliant Sirius and stunning Orion. Astronomers expect Leonid rates could hit 100 per hour at this year's peak. FRANK ZULLO

COMETS AND ASTEROIDS

Asteroid Iris in full bloom

Many asteroids revolve around the Sun in relatively circular orbits between Mars and Jupiter. For example, 1 Ceres has a rounder orbit than Mars, and Ceres' peak brightness remains pretty much the same from one appearance to the next.

In contrast, 7 Iris has a more egg-shape orbit, swinging significantly closer to the Sun every 3.7 years. When the Sun, Earth, and Iris line up at opposition this month, the asteroid lies relatively close to Earth and hits magnitude 6.8, a nice backyard binocular target. The next time we line up, Iris will be almost as far from the Sun as it can get and will glow feebly at magnitude 9.4. Iris won't shine as bright as it does this month for another 11 years.

To locate Iris, set your sights on the beautiful Pleiades star cluster (M45) in Taurus, now rising in the east after darkness falls. Move from the handle of M45's mini-dipper through the bowl by a full binocular field. With the exception of a handful of field stars, Iris will be the brightest object in this region, making it a snap to track this month. Avoid the nights from November 4 to 6, when light from the nearby Full Moon will drown out Iris.

Faye stays strong

Did you happen to watch the fascinating breakup of Comet 73P/Schwassmann-Wachmann 3 this past spring? It surely was a treat, the likes of which we're not likely to see for many years.

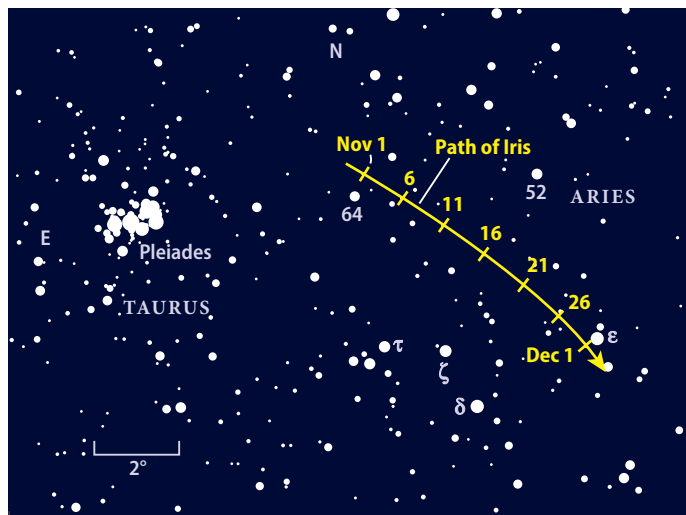
The vast majority of comet nuclei — dirty snowballs of ice and dust — don't go through antics like that, particularly comets that keep their distance from the Sun. This month, Comet 4P/Faye cruises quietly to the east (left) of Alpha (α) Piscium and appears low in the east as twilight descends.

Although you can find this 9th-magnitude comet from a suburban backyard with a 12-inch scope, Faye will look much nicer from rural locations away from streetlights through a 5- or 6-inch scope. (Unfortunately, it lies beyond the reach of typical binoculars.) By November 10, the comet sits decently above the eastern horizon in a dark sky.

A comet looks the way it does because the Sun heats the nucleus' various ices. Sunlight causes these ices — frozen water, carbon monoxide, and carbon dioxide, among others — to sublime, or change directly from a solid to a gas. The small nucleus' weak gravity can't hold onto either the gas or the dust particles released with it.

This gas and dust form an amorphous cloud, called the coma, that surrounds the nucleus and can span a million miles. The Sun's radiation and magnetic field push the coma's gas and dust away from the Sun, creating two separate tails.

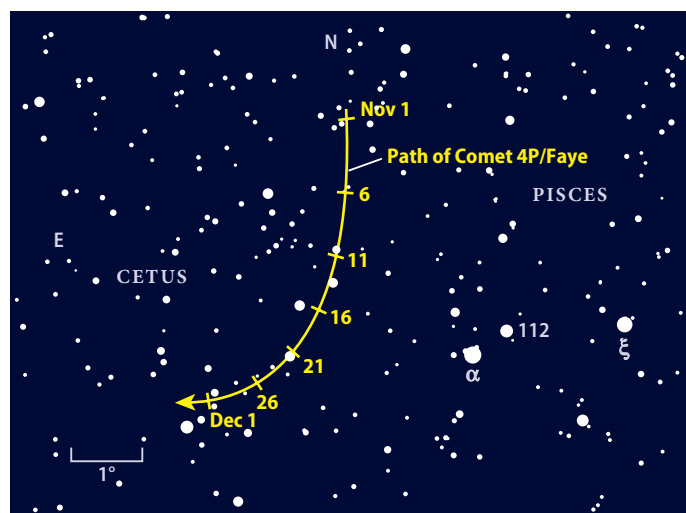
Comet Faye should sport a bright, condensed core and a short tail heading northeast. Astronomers call the starlike



ASTRONOMY: ROEN KELLY

IRIS TRACKS WEST OF THE PLEIADES

throughout November. Only a couple of stars in the vicinity rival the 7th-magnitude asteroid, so spying it will be relatively easy.



ASTRONOMY: ROEN KELLY

COMET 4P/FAYE SPLASHES THE WHALE

this month, digging south along Cetus' border with Pisces. You'll need a 5-inch scope and a dark sky to see the comet's soft glow.

center the "false nucleus" because a shroud of sunlit dust obscures the comet's actual surface. Don't get confused the nights of November 11 and 22,

when the coma passes in front of a bright field star. On the positive side, such a bright marker makes it easy to see the comet move over a few hours. ■

NASA targets distant

New missions to the giant planets
— and their moons — top planetary
scientists' wish lists. /// BY BRUCE MOOMAW

Planetary scientists want to return to the giant planets and their satellites. If they have their way, missions launched in the next couple of decades would include an orbiter to Jupiter's moon Europa, a blimp-based sampling mission to Saturn's smoggy Titan, and a new visit to Neptune and its moon Triton.

Space scientists presented these concepts at last year's meeting of the National Academy of Sciences' Committee on Planetary and Lunar Exploration (COMPLEX) in Irvine, California. COMPLEX is one of NASA's oldest advisory groups. While plans for studying the Moon and Mars figured prominently, the meeting's main focus was the future exploration of the giant planets and their moons.

NASA's non-Mars solar system missions fall into three categories. The first is the low-cost Discovery missions, which the agency expects to fly every 2 years or so. The program has produced some great successes, such as last year's Deep Impact comet mission, but costs have crept upward, largely because NASA has already flown most of the cheap, scientifically useful missions. Last year, NASA did not consider a single proposed mission as being both worthwhile and likely to succeed within the cost cap. Congress has raised the Discovery cap from \$350 million to \$425

Bruce Moomaw is a freelance writer with 40 years of interest in planetary exploration. He is a frequent contributor to Astronomy.

A RETURN to Saturn's moon Titan is on the wish list of many planetary scientists. Some think the best way to understand this unusual moon is to hover in the atmosphere using a blimp or hot-air balloon. As the balloon-probe cruises through the atmosphere, it can descend and retrieve surface samples for analysis.

MICHAEL CARROLL FOR ASTRONOMY

{ PLANETARY EXPLORATION }

ant worlds



million. This should provide enough elbow room for new and interesting proposals.

The second category, which caps costs at \$800 million, is called New Frontiers. The first mission in this category is the New Horizons Pluto flyby, which launched this January. NASA would like to fly a New Frontiers-class mission every 3 years. The next New Frontiers spacecraft, slated for launch by mid-2010, is to be a Jupiter orbiter named Juno. But with the current budget outlook, a third New Frontiers mission may not fly before 2015.

On to Europa

NASA's third mission category includes the billion-dollar Flagship probes, which would launch at most twice per decade. A Europa orbiter ranks highest on this list. Space scientists agree that a detailed study of Jupiter's icy moon and its suspected subsurface ocean is among the highest-priority missions.

The Europa Geophysical Explorer (EGE) is one concept being considered. Placed into a low-polar orbit around the moon, EGE would measure the tidal flexing of Europa's icy crust to establish the ocean's presence. It also would provide detailed surface images and probe the crust's upper few miles using radar to look for near-surface fissures and pockets filled with liquid water. Although EGE's radar probably can't punch deep enough through the ice to reach Europa's liquid water, it can look for places where warm ice has transported substances upward from the underlying ocean.

As currently envisioned, EGE may even carry an instrumented probe that would land on the moon's surface. Part of EGE's mission is to identify sites for future landers that would search for the chemical and microscopic remnants of life dredged up from the ocean below.

EGE must carry fuel to brake itself into orbit around Europa, as well as over 400 pounds (180 kilograms) of metal shielding to protect itself from Jupiter's savage radiation environment. This will give EGE 18 months in Jupiter orbit — time needed to set up its Europa arrival — and at least 1 month at Europa itself.

If funding for the \$1.2 billion project materializes, a mission like EGE could

launch by 2015. But NASA's belt-tightening has, however, placed any Europa orbiter on indefinite hold.

Return to Titan

Scientists are debating the target of NASA's post-Europa Flagship-class mission. The odds-on favorite is Saturn's smog-shrouded moon Titan.

Cassini began studying Titan as soon as it arrived at Saturn in 2004. Together with its Huygens probe, which landed on the moon in January 2005, the spacecraft have revealed a moon even more fascinating than expected. Titan is host to liquid-methane drizzle and even violent rainstorms that

sands of years. Having oxygen available in these places allows complex oxygen-containing organic molecules — chemicals that may resemble so-called prebiotic compounds on early Earth — to form. Titan, although abysmally cold and hostile to life as we now know it, may provide the key to understanding the biochemical reactions that eventually led to life on Earth.

Scientists have a lot more to learn about this strange place before they can outline the next Titan mission. A Titan orbiter or a non-landing balloon could reveal much about the moon's complex surface geology and its weather, but it couldn't analyze the surface. A stationary lander or a rover

could analyze the surface in detail at one place, but it might not land at the most interesting place, such as a recent water-ammonia lava eruption. So, scientists are considering proposals involving an aircraft that could travel thousands of miles and repeatedly land to scoop up samples from different places.

Wayne Zimmerman, an engineer at the Jet Propulsion Laboratory (JPL) in Pasadena, California, described such a concept at the COMPLEX meeting. His Titan Organics Explorer (TOE) is a 46-foot-long (14 meters) hydrogen-filled blimp that would cruise through Titan's smog at altitudes between 2,500 and 5,000 feet (800 to 1,600 m). It could spend a week zigzagging over an interesting area, look for the best sampling site, and then swivel its motors to descend within 150 feet (46 m) of the surface. It would then drop a sampling

device, which would fire a coring tube into the surface. The blimp would reel the tube back up and begin analyzing the contents while cruising to its next target.

Zimmerman designed TOE to send all its data directly back to Earth. If NASA launches such a mission before about 2020, when Saturn's north pole tips toward Earth, the vehicle will be restricted to Titan's north polar regions to retain its line-of-sight communication with Earth. As it happens, the best evidence for surface liquids on Titan happens to be the so-called land of lakes area in the far north.

Such a mission would be costly, so Zimmerman has developed a budget version with an unmotorized hot-air balloon that

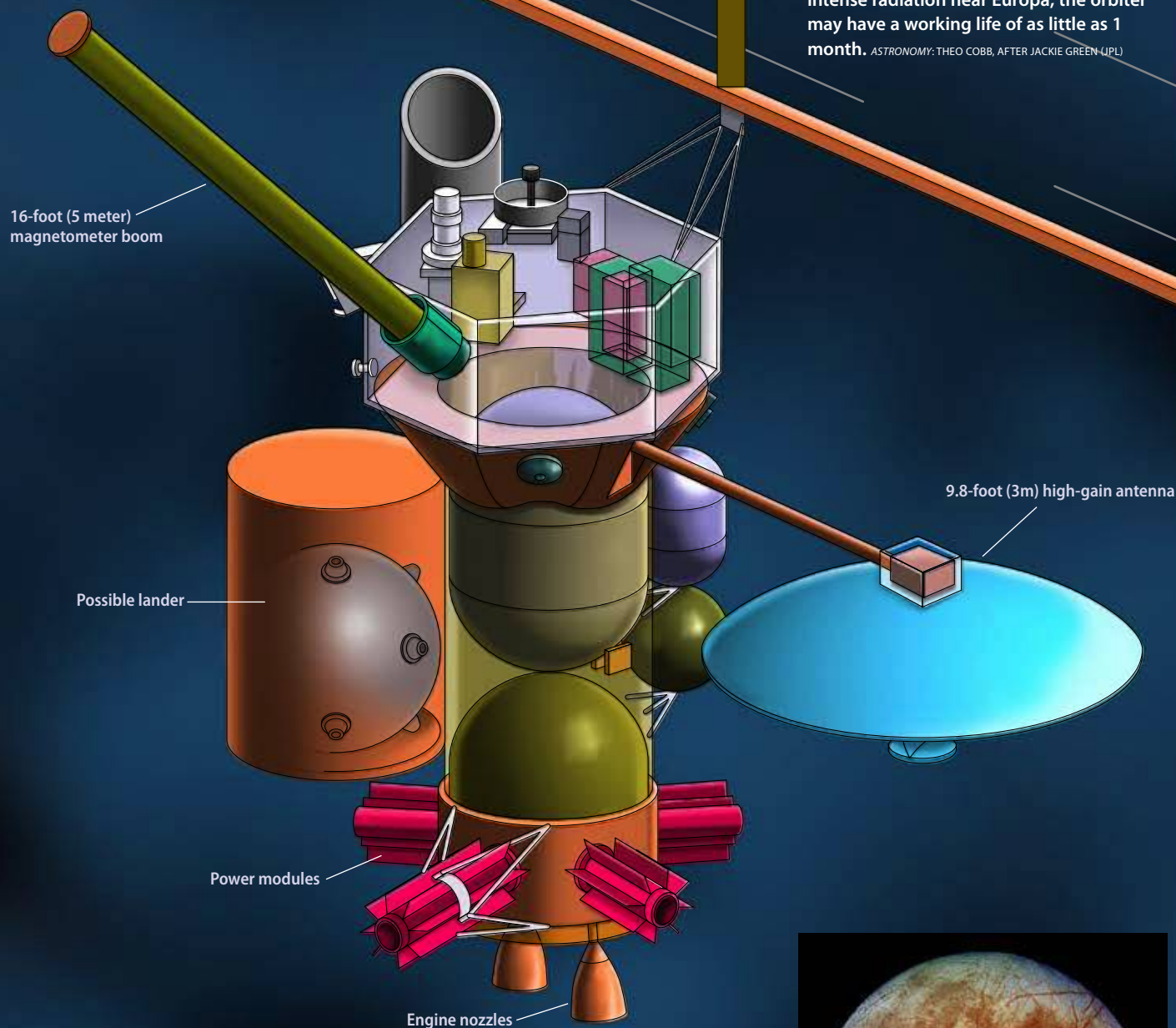


TITAN, Saturn's largest moon, offers a twisted glimpse of earthlike processes: Ice volcanoes form continents, and storm clouds rain methane. NASA/JPL/SSI

erode its icy landscape. The most important new finding, however, may be the confirmation that Titan is a world of frequent volcanic activity — more properly, cryovolcanic activity, for what erupts on Titan is a pasty mixture of water and ammonia. The substance flows like a liquid at temperatures down to -170°F (-112°C) but then freezes solid after it erupts onto the -290°F (-178°C) surface.

The Sun's ultraviolet light and Saturn's radiation transform Titan's air into complex organic compounds that rain onto the surface. Because Titan's surface is so cold, most of the oxygen there is locked away in ice. But water may be available in cryovolcanic areas — perhaps for periods lasting thou-

How to make a European orbiter



THE EUROPA Geophysical Explorer includes a radar sounder that would penetrate the moon's icy crust, although probably not far enough to reveal the suspected ocean. The probe may accommodate a small lander. Because of the intense radiation near Europa, the orbiter may have a working life of as little as 1 month. *ASTRONOMY: THEO COBB, AFTER JACKIE GREEN (JPL)*

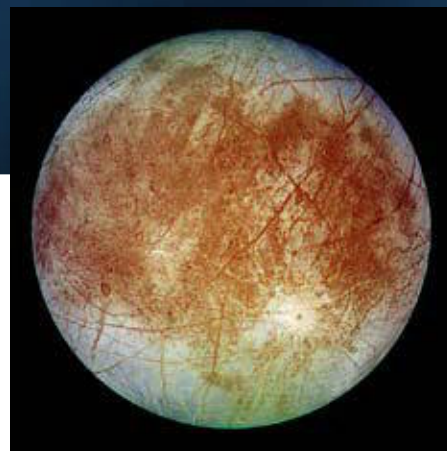
keeps the cost in the \$1 billion range. A heater would warm Titan's air to inflate the balloon, which would coast along in Titan's slow easterly breeze some 16,000 feet (5,000 m) up. Controllers could temporarily vent the balloon to drop down and fire harpoons into the surface to acquire samples.

Still, it's clear scientists need to know a lot more about the conditions on Titan before anyone can move forward with such a mission. Cassini's remaining observations, over at least the next 2 years, will help

fill in crucial gaps in our knowledge about this exciting and intriguing world.

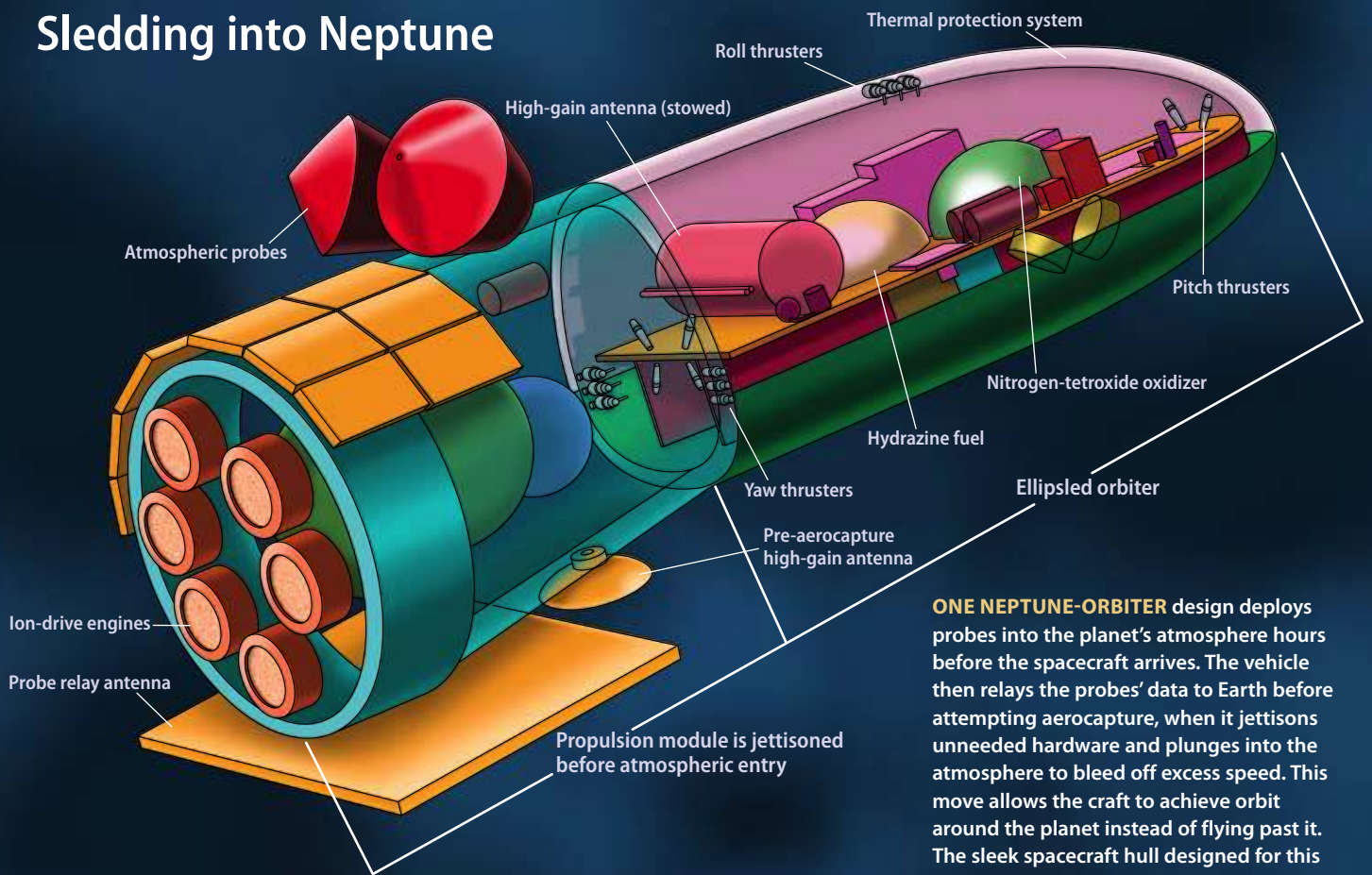
Enter the giants

While scientists generally agree NASA's next big outer-solar-system missions should target Europa and Titan, other mission designs are also in the works. One likely goal is dropping entry probes into the atmospheres of giant planets. One such probe, dropped in 1995 by the Galileo mission, already has parachuted into Jupiter's



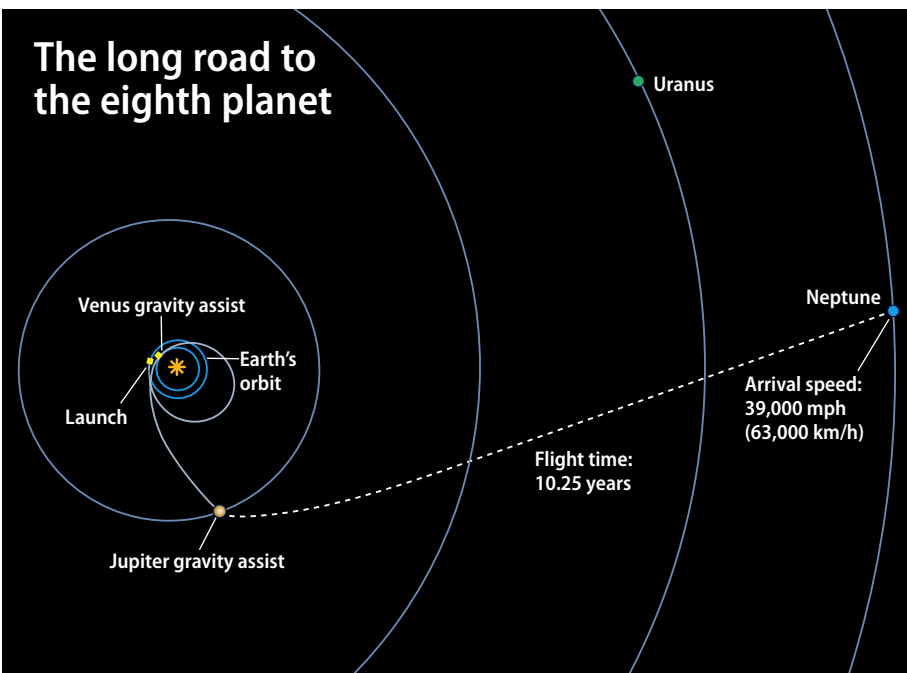
EUROPA'S ICY SHELL may cover a global ocean, but it will take a dedicated spacecraft mission to prove it. *NASA/JPL*

Sledding into Neptune



ONE NEPTUNE-ORBITER design deploys probes into the planet's atmosphere hours before the spacecraft arrives. The vehicle then relays the probes' data to Earth before attempting aerocapture, when it jettisons unneeded hardware and plunges into the atmosphere to bleed off excess speed. This move allows the craft to achieve orbit around the planet instead of flying past it. The sleek spacecraft hull designed for this maneuver is called an "ellipsled." ASTRONOMY: THEO COBB, AFTER A. INGERSOLL AND T. SPILKER (JPL)

The long road to the eighth planet



A SPACECRAFT launched on a Delta IV rocket could reach Neptune in less than 11 years. The feat would require two gravity assists, one from Venus and one from Jupiter. Arrival speeds could be higher than 39,000 mph (63,000 km/h), requiring the use of Neptune's atmosphere to slow the spacecraft into orbit. ASTRONOMY: THEO COBB, AFTER A. INGERSOLL AND T. SPILKER (JPL)

atmosphere. This provided scientists with great new information, but, at the COMPLEX meeting, JPL's Scott Bolton, principal investigator for the Juno Jupiter orbiter, described one important measurement the Galileo probe did not make.

The giant planets likely formed out of initial accumulations of rock and ice that became so massive, their gravity attracted huge shares of hydrogen and helium from the solar nebula. The Galileo probe was to confirm this hypothesis by measuring the abundance of elements heavier than helium in Jupiter's atmosphere.

The surprising results: carbon, nitrogen, sulfur, and the heavier noble gases, like krypton, each were about 3 times more abundant than in the Sun. This suggests that either Jupiter formed much farther from the Sun than it is now, where the water-ice chunks carrying those elements were colder, or those ice-trapped elements occurred in a less concentrated form (called clathrates) than scientists thought.

To decide which scenario is true, scientists need to sample oxygen in water vapor

in Jupiter's atmosphere. But the Galileo probe descended in a hot spot where water is abnormally scarce, and it couldn't make the crucial measurement. One of the Juno orbiter's main goals is to probe Jupiter's atmosphere from orbit to nail down how much oxygen the planet really has. But scientists need similar data for Saturn, Uranus, and Neptune.

Until recently, scientists thought they'd need entry probes that could survive to pressures of about 100 bars (1 bar is Earth's surface pressure). But Bolton described the growing belief that atmospheric probes can make the measurements scientists most need at depths of only about 20 bars for Saturn and 40 bars at Uranus and Neptune. This means we can explore all three giant worlds with lightweight, Galileo-style probes that are vented to the outside air instead of costly pressurized craft.

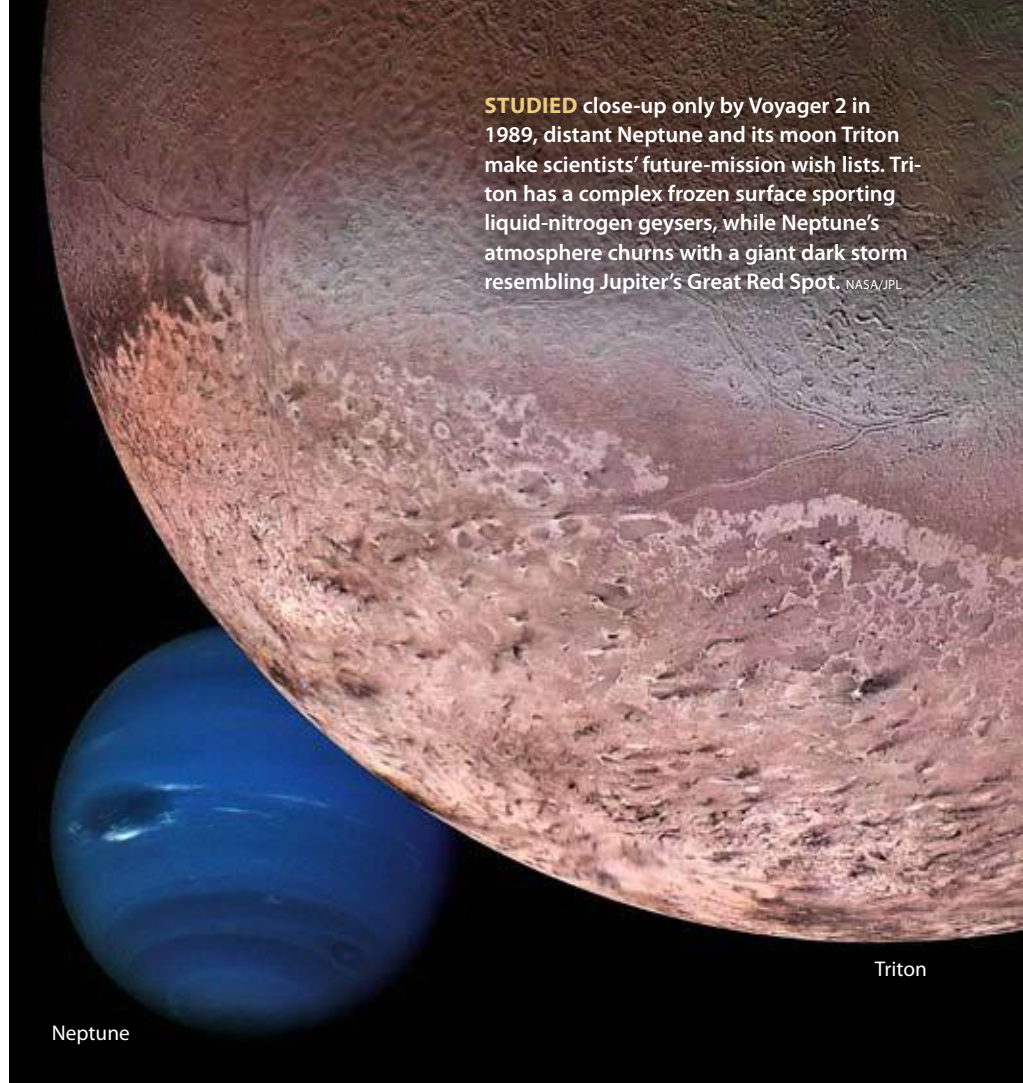
A relatively simple flyby craft could drop two or three such probes at Saturn. But for Uranus and Neptune, scientists would like the type of detailed mission they had at Jupiter with Galileo and at Saturn with Cassini. And, as JPL's Jeffrey Hall points out, such an orbiter mission — already complex and expensive enough for the innermost giant planets — is considerably tougher at Uranus and Neptune. In order to get a spacecraft to either of these distant worlds with an acceptable flight time of 10 to 15 years, the vehicle arrives at such a high speed that it needs an inordinate amount of fuel to slow into orbit.

The answer lies in an as-yet-untried technique called aerocapture. The arriving orbiter folds up behind a protective heat shield and skims through the outer fringes of the planet's atmosphere, slowing itself down by thousands of miles per hour without burning any rocket fuel.

The orbiter then ejects its heat shield, coasts up to the high point of its new orbit around the planet, and fires its engine for a relatively short burn. This raises the low point of its next orbit so the craft stays out of the atmosphere. After this, the spacecraft can get down to business.

Flying into Neptune

Aerocapture requires precision guidance, but no more so than landing vehicles' targeted entries and touchdowns. But the technique is more difficult for the outer planets than it is for Mars and Venus. This is partly because the entry speed at the



STUDIED close-up only by Voyager 2 in 1989, distant Neptune and its moon Triton make scientists' future-mission wish lists. Triton has a complex frozen surface sporting liquid-nitrogen geysers, while Neptune's atmosphere churns with a giant dark storm resembling Jupiter's Great Red Spot. NASA/JPL

giants is much higher (more than 39,000 mph [63,000 km/h] at Neptune). But it's also harder to target precisely the atmospheric entry paths of probes in the outer solar system. For giant-planet aerocaptures, a spacecraft needs a boat-shape heat shield that generates lift so the probe can respond more rapidly to the autopilot's course changes during the entry.

Scientists say a single flight test on Earth will be enough to give them confidence in the guidance programs developed for aerocapture. Such a test, which would use Earth's atmosphere to transfer a small satellite in a large elliptical orbit into a tight, low orbit, could launch as early as 2009. Aerocapture could lead to great fuel-weight savings on future orbiters, but, to pull off the technique at the giant worlds, engineers will need to develop new heat-shield designs.

Neptune, despite its greater distance, is considered a higher-priority target than Uranus primarily because of its big, ice-geyser-peppered moon Triton. A recent Neptune-orbiter concept would drop two entry probes into the planet's atmosphere at

different latitudes. The main craft would receive the probes' data a few hours before the orbiter plowed through the atmosphere's outer fringes, slowing into an elongated orbit around Neptune. The craft would then spend 3 years making more than 40 Triton flybys. These flybys would allow detailed studies of the moon, but the orbiter would also use Triton's gravity to attain different orbits for close-up views of other interesting targets. Such a mission would cost several billion dollars, and a launch seems unlikely before the late 2020s.

COMPLEX and NASA's other advisory groups are working to shape the future of planetary exploration by leveraging knowledge we've gained against what we have yet to learn. These groups play vital roles by identifying the best science goals despite budgetary realities. The road ahead in space exploration may be uncertain, but thanks to forward-looking scientists and engineers, exciting possibilities lie before us. ■

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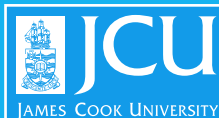
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DEEP-SKY OBSERVING

Not all galaxies fall under the category “faint fuzzies.” This list will rock your universe. /// BY MICHAEL E. BAKICH

Observe fall's top galaxies

Now that summer's gone, observers the world over can train their telescopes on a new set of targets — galaxies. We see galaxies best in the fall and spring because the Milky Way's stars, gas, and dust no longer block them from view. Nineteenth-century astronomers termed the

lack of galaxies within the Milky Way's luminous band the “zone of avoidance.”

Starting strong

The first galaxy on our list ranks as the ultimate northern deep-sky object — the **Andromeda Galaxy** (M31). From a dark site, you'll see it with your naked eyes as a hazy patch of light. In fact, M31 looks like a small, detached piece of the Milky Way. Find it 1° west of Nu (ν) Andromedae. M31 measures more than 3° long. That's 6 Full Moons side by side.

The Andromeda Galaxy is a showpiece through any telescope. Small scopes with eyepieces that give a wide field of view allow you to study the galaxy's overall structure. Can you see the dark dust lane that defines M31's western edge? Move up to a 6-inch scope at a dark site, and you'll see two dust lanes.

Larger telescopes allow you to crank up the magnification and study individual features. The brightest of these has its own designation: NGC 206 is an association of young, hot stars on the southern end of the galaxy's spiral ring.

The Andromeda Galaxy's globular clusters also are worthy targets for large scopes. Easiest to see is G1, 2½° southwest of M31's

center. G1 measures 10" across — about half as large as Mars ever gets.

M31's two bright companions, **M32** and **NGC 205**, are small elliptical galaxies. Such objects normally appear featureless, and these two galaxies have an additional disadvantage: their positions near M31.

If you choose the Andromeda Galaxy as your first target, what do you do for an encore? Believe it or not, another galaxy, nearly as bright as M31, lies nearby.

If you're observing from a light-polluted site, point your scope 4° west of magnitude 3 Alpha (α) Trianguli to find the **Pinwheel Galaxy** (M33). From a dark site, no such directions are required because M33 shines brightly enough to be visible.

Through a telescope, M33 explodes into detail. At low magnification, you'll detect its multiple spiral arms. Nudge the power up past 100x, and bright stellar associations and star-forming regions pop into view. A 12-inch or larger telescope gives you a good view of emission nebula NGC 604. Increase the magnification past 250x, and you'll notice this nebula looks like a small version of a spiral galaxy. Two “arms” seem to emanate from the central “core.”

In the case of most galaxies, using any type of astronomical filter only dims the view. That happens because galaxies, unlike nebulae, emit lots of light in all wavelengths. M33 shines so brightly, however,

that you can break this rule. A nebula filter actually can help you pick out emission nebulae within its spiral arms.

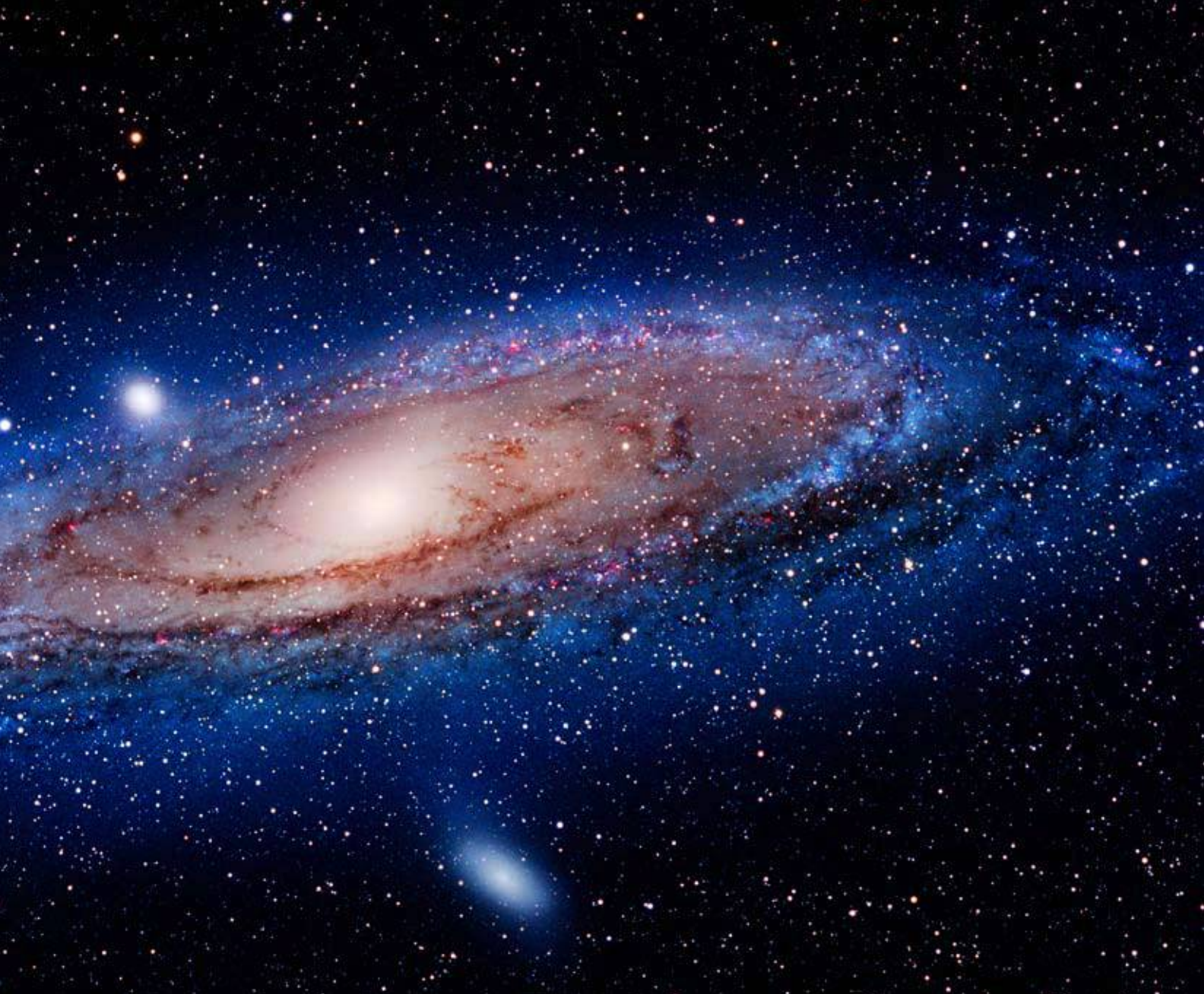
Southern pair

Two large but faint constellations dominate the fall sky — Cetus the Whale and Pisces the Fish. French comet-hunter Charles Messier (1730–1817) listed only one deep-sky object in each of these giant constellations, but a patient observer equipped with an 8-inch or larger telescope under a dark sky will see many more.

The showpiece object in Cetus is **M77**. This magnitude 8.9 spiral galaxy lies less than 1° east-southeast of Delta (δ) Ceti. Through a 4-inch telescope, M77's core appears starlike with a wispy halo. Because the halo is denser to the northwest, M77

Michael E. Bakich is a senior editor of *Astronomy*.





▲ **THE SKY'S** greatest galaxy, the Andromeda Galaxy (M31), offers something of interest to observers at all levels. At low magnifications, you'll see this galaxy's overall structure and two satellite galaxies, M32 and NGC 205. Increase your scope's size, and dust lanes appear within the spiral arms. TONY AND

DAPHNE HALLAS

► **LESS THAN 15°** from M31 lies another showstopper — the Pinwheel Galaxy (M33). M33 is one of the few galaxies that benefits from a nebula filter. Using this accessory makes it easier to see star-forming regions within M33's spiral arms. DANIEL B. PHILLIPS

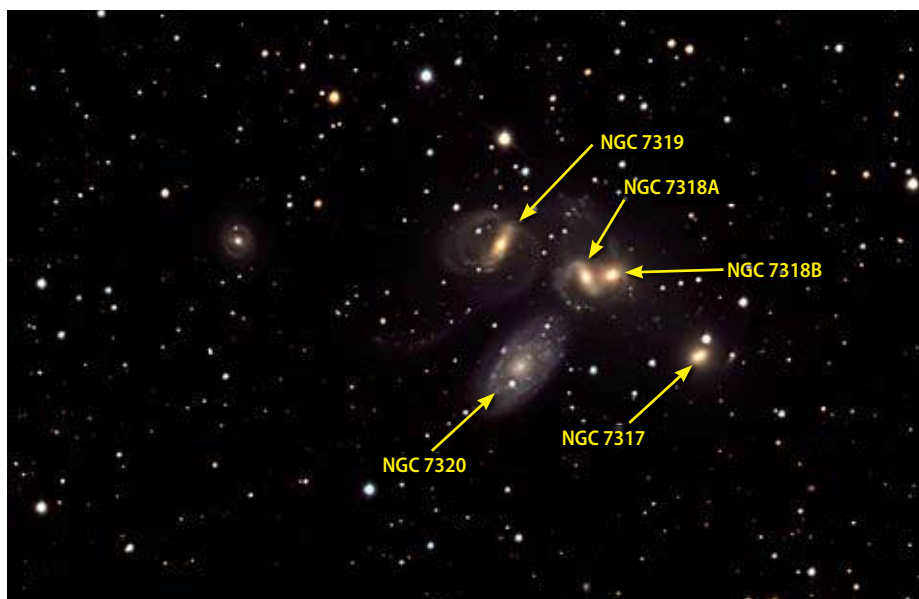




LARGE TELESCOPES best reveal M74's secrets. This classic face-on spiral contains tightly wound arms and a starlike core. Use a nebula filter to examine the huge glowing gas clouds in M74's spiral arms more closely. ADAM BLOCK/NOAO/AURA/NSF



SPIRAL GALAXY NGC 2403 in Camelopardalis lies not quite 8° northwest of Omicron (o) Ursae Majoris, the brightest star near NGC 2403. This magnitude 8.3 galaxy measures 18' by 11' and lies only 12 million light-years away. FRED CALVERT/ADAM BLOCK/NOAO/AURA/NSF



SIMPLY SEEING STEPHAN'S QUINTET (NGC 7317, NGC 7318A, NGC 7318B, NGC 7319, and NGC 7320) does not pose a challenge. You can glimpse the brightest member, magnitude 12.5 NGC 7320, through an 8-inch scope. To see detail in these wispy objects, however, you'll need at least a 16-inch telescope. ADAM BLOCK/NOAO/AURA/NSF

has a comet-like appearance. A magnitude 10 star glows 1.5' to the east-southeast. An 8-inch or larger scope reveals structure in the central 2' of this 8' by 7' galaxy, but you'll need at least 12 inches of aperture to resolve the tightly wound spiral arms.

Almost exactly 0.5° north-northwest of M77 lies the equally beautiful edge-on spiral **NGC 1055**. You'll see both galaxies in any eyepiece that shows you the entire Full Moon, and they're quite a sight through a large telescope. Through a 6-inch scope, you'll see a 4' by 1' spindle aligned east-west. Increase your aperture to 10 inches, and you'll notice the dust lane that cuts the

galaxy in two lengthwise. The dark lane's northern edge is easiest to spot.

The great face-on spiral galaxy **M74** is Pisces' highlight object. Find it 1.3° east-northeast of Eta (η) Piscium. M74 extends 10' in diameter. Even a 2.4-inch telescope shows half the galaxy's extent, but a large scope (12 inches and above) reveals both stellar associations and gas clouds. The core is broad — 2.5' across — and condensed. Adding to M74's appearance, six stars lie in our line of sight to this galaxy, two of them superimposed on its nucleus.

Moving to Pisces, look slightly more than 2° southwest of Mu (μ) Piscium for

spiral galaxy **NGC 488**. The outer regions of this magnitude 10.3 object are difficult to see, but the central 1' is bright and gets brighter toward the core.

Spiral galaxy **NGC 676** shines at 10th magnitude, or maybe 11th. The uncertainty comes from a magnitude 9.5 star positioned in front of the galaxy's nucleus. The star is bright enough that you'll have trouble seeing the galaxy through a 6-inch telescope. Through a 12-inch, however, NGC 676 appears lens-shaped, measuring 3' by 1' and aligned roughly north-south.

Small but mighty

Once you've checked the powerhouse Messier galaxies off your list, many others — albeit smaller and fainter — await you. Find 2nd-magnitude Gamma (γ) Andromedae, then move 3½° east to spiral galaxy **NGC 891**. Veering only 1.4° from being exactly edge-on, NGC 891 is 4 times as long as it is wide, has a large, bright nucleus, and is split lengthwise by a dark dust lane. Once you point a 10-inch or larger scope at NGC 891, you'll see why it makes so many "top 10" best-to-observe galaxy lists.

Early in the fall, point your scope 1¾° northeast of Omega (ω) Draconis. Here, you'll find **NGC 6503**, a 10th-magnitude spiral that even a 4-inch scope reveals. NGC 6503 is roughly 3 times as long as it is wide. Its central region appears elongated, and the brightest part is not quite centered.

In Pegasus, look for magnitude 9.5 spiral galaxy **NGC 7331**, which lies a bit more than 4° north-northeast of Eta Pegasi. This galaxy is part of a group that numbers less than a dozen. Use a low-power eyepiece



IN MOST CONSTELLATIONS, NGC 891 would be the highlight object. In Andromeda, however, it must defer to M31. Still, it's worth spending time observing this 10th-magnitude galaxy. Look for the dust lane that splits NGC 891's length. ADAM BLOCK/NOAO/AURA/NSF



CETUS THE WHALE'S sole Messier object is M77. You'll have no trouble seeing the central regions of this 9th-magnitude spiral galaxy, but its arms reveal their details only through 12-inch and larger telescopes. FRANCOIS AND SHELLEY PELLETIER/ADAM BLOCK/NOAO/AURA/NSF

FALL'S TOP TWO DOZEN GALAXIES

Name	R.A. (2000.0)	Dec. (2000.0)	Mag.	Size
NGC 55	0h15m	-39°13'	8.1	31' by 6'
M31	0h43m	41°16'	3.5	189' by 62'
NGC 253	0h48m	-25°17'	7.6	29' by 7'
NGC 300	0h55m	-37°41'	8.1	20' by 13'
Sculptor Dwarf	1h00m	-33°42'	8.8	66' by 48'
NGC 488	1h22m	5°15'	10.3	5.4' by 3.9'
M33	1h34m	30°39'	5.5	69' by 42'
M74	1h37m	15°47'	9.1	10.5' by 9.5'
NGC 676	1h49m	5°54'	11.9	4' by 1'
NGC 772	1h59m	19°00'	10.3	7.2' by 4.3'
NGC 891	2h23m	42°21'	10.1	11.7' by 1.6'
NGC 1055	2h42m	0°27'	10.6	7.6' by 2.7'
M77	2h43m	-0°01'	8.9	7.1' by 6' NGC
NGC 1097	2h46m	-30°17'	9.5	9.4' by 6.6'
NGC 1291	3h17m	-41°06'	8.5	11' by 9.5'
NGC 1300	3h20m	-19°25'	10.4	6.2' by 4.1'
NGC 1365	3h34m	-36°08'	9.3	11' by 6.2'
NGC 1399	3h38m	-35°27'	9.4	6.9' by 6.5'
NGC 1404	3h39m	-35°36'	10.0	3.3' by 3'
NGC 1421	3h42m	-13°29'	11.4	3.4' by 0.8'
NGC 2403	7h37m	65°36'	8.2	17.8' by 11'
NGC 6503	17h49m	70°09'	10.2	7' by 2.5'
NGC 7331	22h37m	34°25'	9.5	10.5' by 4.2'
NGC 7320	22h36m	-12°27'	12.7	2.2' by 1.1'

Key: R.A. = Right ascension; Dec. = Declination; Mag. = Magnitude



OBSERVERS tout NGC 1365 in Fornax as the sky's finest barred spiral galaxy. This object's bar glows yellow, while the arms combine blue from young stars and red from star-forming regions. NGC 1365 lies 60 million light-years away. DANIEL VERSCHATSE

through a 10-inch scope to see several other members. NGC 7331 is 10.5' long and one-third as wide. The bright, elongated central region washes out the fainter spiral arms through telescopes less than 12 inches in aperture.

Finally, if you have access to a large scope, train it on **Stephan's Quintet** (NGC

7317, NGC 7318A, NGC 7318B, NGC 7319, and NGC 7320), a collection of galaxies ½° southwest of NGC 7331. In the quintet, NGC 7320 is brightest, glowing meekly at magnitude 12.7. The faintest, NGC 7317, shines 4 times fainter at magnitude 15.3.

Next, find the bright spiral galaxy **NGC 2403** in Camelopardalis. In astronomy,

"bright" is a relative term, but this galaxy ranks among the top 100 brightest galaxies visible from Earth. Through a 6-inch scope, you'll see an oval patch 7' wide with an obvious central brightening.

Hop over to Aries, and, a bit more than 1° east of Gamma Arietis, you'll find spiral galaxy **NGC 772**. This magnitude 10.3



TEST BOTH your vision and the quality of your observing site by trying to spot the Silver Coin Galaxy (NGC 253) in Sculptor with your naked eyes. Only observers with the keenest vision will see

this magnitude 7.6 object, and then only when it climbs high enough in the sky. NGC 253 measures 29' across — nearly the diameter of the Full Moon. DOUG MATTHEWS/ADAM BLOCK/NOAO/AURA/NSF

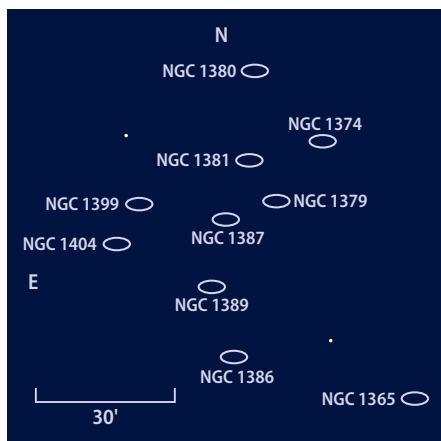
object measures more than 50-percent longer than it is wide (7.3' by 4.6'). NGC 772 also classifies as a peculiar galaxy, mainly due to its gravitational interaction with **NGC 770**. With a 12-inch or larger scope and some patience, you can spot the nucleus of magnitude 13 NGC 770 just off the southern edge of NGC 772's halo.

Into the furnace

Find the star Beta Fornacis, and then move 2° north to the barred spiral galaxy **NGC 1097**. The core is this galaxy's bright point, then the bar, which extends in a northwest to southeast direction, and, finally, the spiral arms. You'll need at least a 12-inch telescope, a dark sky, and good seeing to see this last feature.

The **Fornax galaxy cluster**, near that constellation's eastern border, ranks as one of the sky's best known. From a dark observing site, an 8-inch telescope will let you see dozens of galaxies within a several-degree-wide swath.

One of the brightest members of the Fornax cluster is magnitude 9.3 **NGC 1365**, an object most observers consider the finest barred spiral galaxy in the sky. Its bar extends 4' in an east-west orientation; the central 2' is the nucleus. An 8-inch telescope easily resolves the spiral arms, of which the northern — extending from the west end of the bar — is the brightest.



THE FORNAX CLUSTER of galaxies lies approximately 60 million light-years away. Most of its members classify as elliptical galaxies, but the exception is barred spiral galaxy NGC 1365, which you'll notice first. The field of view shown here measures roughly 1.5° by 1.5°. ASTRONOMY: RICK JOHNSON

The Fornax galaxy cluster's central region spans a scant 2°, but, through a 16-inch telescope, you'll see it encompasses more than 100 galaxies. Even a 6-inch scope will show you several dozen.

Start with **NGC 1374**. This magnitude 11 galaxy is 2.5' across and has a fainter companion (NGC 1375) 3' to the south. Pan ¼° southeast to reach **NGC 1379**, a similarly bright elliptical galaxy. Move north ½° to **NGC 1380**. This magnitude 10 barred spiral shows a 4.5' by 2.5' oval with a magnitude 13 star just to the west. Nearby, you'll notice magnitude 11.5 **NGC 1381** and magnitude 10.8 **NGC 1387**.

Finally, in the same high-power field of view, you'll see the twin elliptical galaxies **NGC 1399** and **NGC 1404**. Magnitude 8.8 NGC 1399 ranks as the Fornax galaxy cluster's brightest member. At magnitude 9.7, NGC 1404 is fainter and smaller.

Floating on the river

Head south from Fornax into Eridanus the River, and observe the barred spiral galaxy **NGC 1291**. You won't see the bar of this magnitude 8.5 galaxy, but you will see its oval shape and intense core.

Also in Eridanus, the classic barred spiral galaxy **NGC 1300** deserves your attention. This barred spiral galaxy lies 2° north of Tau⁴ Eridani and glows at magnitude 10.4. The galaxy's nucleus stands out nicely. Next in order of visual prominence are two nodules at the ends of the bar. Most difficult to see are NGC 1300's spiral arms, which wind tightly around the inner parts.

Look a bit more than 1.5° southwest of Pi Eridani for peculiar galaxy **NGC 1421**. Barely visible through a 6-inch scope, NGC 1421 shows lots of detail through a 10-inch at 150x. It appears spindle-like (3' by 0.5'), with its long axis aligned north-south. Crank up the power to 300x, and you'll see irregular structure in the form of several knotty regions. The core, which stretches 1', appears brighter on its northern end.

Sculptor's jewels

Now, let's move from Eridanus into Sculptor. When you target objects in this constellation, you'll want to set aside a good

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Print out handy finder charts for these galaxies by going to www.astronomy.com/toc.



OBSERVE NGC 772 in Aries, and note its weird shape. This spiral galaxy's arms are being distended by dwarf elliptical galaxy NGC 770, which lies only 3' to the south-southwest. ADAM BLOCK/NOAO/AURA/NSF



IF YOUR SOUTHERN HORIZON dips low enough, you may be able to see both the Pinwheel Galaxy (M33) and this object, dubbed the Southern Pinwheel (NGC 300), at the same time. DANIEL VERSCHATSE

portion of the night. No less than four named galaxies lie here, and each shines brighter than 9th magnitude.

Find the **Cigar Galaxy** (NGC 55) about 4° northwest of Alpha Phoenicis. This galaxy lies 5 million light-years away and shines at magnitude 8.1. Nearly ½° long, the Cigar Galaxy is unusual because most of its stars are offset west of center, rather than concentrated in its core. This galaxy is one of the few that benefits from a nebula filter. Such a filter suppresses NGC 55's stars, and several large ionized hydrogen clouds pop into view.

Another magnitude 8.1 galaxy in Sculptor is the **Southern Pinwheel Galaxy** (NGC 300), which resembles its northern namesake, the Pinwheel Galaxy (M33) in Triangulum. Because this galaxy appears face-on, however, the Southern Pinwheel has a much lower surface brightness than NGC 55. To see NGC 300's spiral arms well, you'll need a wide-field eyepiece on a 12-inch or larger telescope.

The **Sculptor Dwarf Galaxy**, like the Fornax Dwarf, belongs to the Local Group of galaxies. Lying only 250,000 light-years away, the Sculptor Dwarf shines at magnitude 8.8. Don't let that brightness fool you, however. The Sculptor Dwarf is spread over more than 1° of sky, so its surface brightness is low. Use a wide-angle eyepiece in an 8-inch scope under a dark, transparent sky, and you may see a diffuse haze just brighter than the background.

Sculptor's fourth named star system is the **Silver Coin Galaxy** (NGC 253), the



SPIRAL GALAXY NGC 7331 in Pegasus was one of the first galaxies recognized as a spiral. NGC 7331 is one of 18 galaxies chosen by the Hubble Space Telescope Key Project on the Extragalactic Distance Scale for observation of Cepheid variable stars — key distance markers in the universe. It lies 49 million light-years away. R. JAY GABANY

showpiece deep-sky object in this region of sky. Observers with superb vision may see the magnitude 7.6 glow of this object with unaided eyes under perfect conditions and if NGC 253 is high enough in the sky. This galaxy measures 29' (nearly the diameter of the Full Moon) by 7'.

Contrary to popular belief, galaxies are not difficult to observe. All that's required is a high-quality 6-inch or larger telescope,

a dark sky, and some patience. Remember to change eyepieces frequently, which will allow you to view at different magnifications. That's all you need to get the most out of observing fall's galaxies.

Once you've tracked down some of these galactic gems, you won't be able to help yourself from venturing further into the deep sky, going boldly where you've never gone before. Have a nice trip. ■

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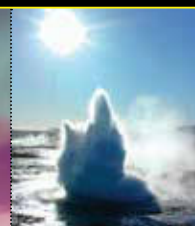
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METEOR-SHOWER OBSERVING

Moonless nights promise dozens of meteors per hour at this shower's peak. /// BY BILL COOKE

Get ready for the Leonids

During the night of November 12, 1833, the Leonid meteor shower put on such a spectacular display that many people thought the world was coming to an end. While this year's show won't cause the crowds to panic, its fiery streaks are sure to please the masses.

Fireworks display or not, the attention paid this shower is merited; the Leonids are responsible for the birth of meteor science and for meteor-shower forecasting, a modern art upon which the spacecraft community depends.

Astronomers in the early 1800s noted that all of the meteors appeared to come from the same direction. When traced back, the meteors' paths intersected at the constellation Leo the Lion, near its head. We call

this location the radiant. Meteor showers are named after the constellations that contain the radiant — the Leonid radiant is in Leo. When astronomers realized shower meteoroids orbit the Sun, they deduced that the Leonids move in an orbit with a period of 33 or 34 years. Thus began meteor science.

The Leonids continued to dazzle. In 1866, and again in 1867, observers witnessed meteor rates of several thousand per hour. Because of these awe-inspiring dis-

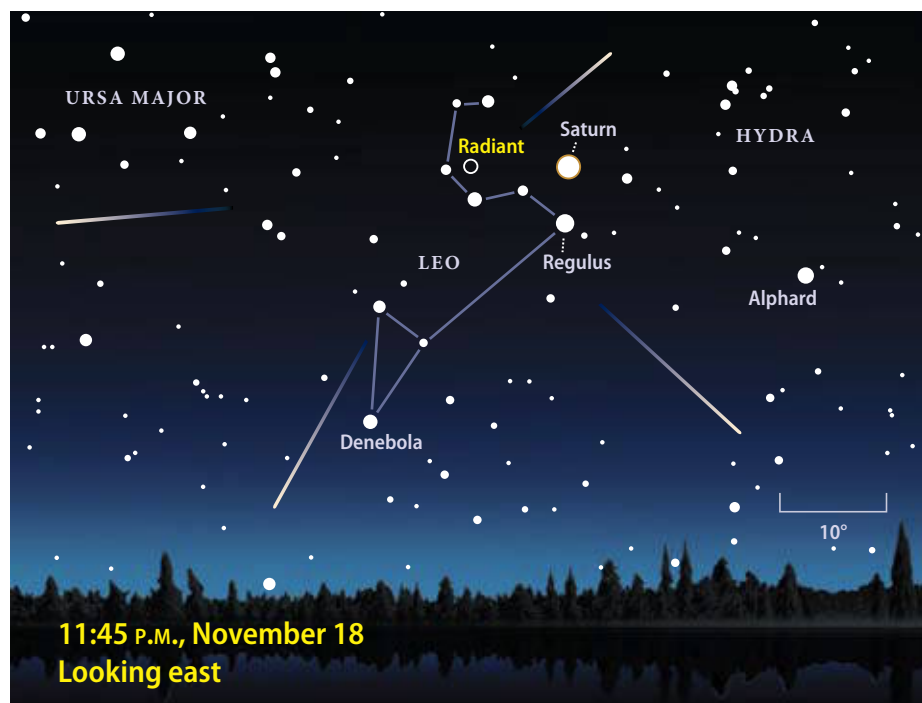
plays, people came to expect fireworks from the Leonids about every 33 years.

Later on in the 1800s, astronomers noticed shower meteoroids' orbits are similar to those of comets. This similarity suggested the meteoroids were debris cast off from comets passing close to the Sun. The Leonids were soon identified as debris left from Comet Tempel-Tuttle. The comet was discovered independently by William Tempel in December 1865 and by Horace Tuttle in January 1866, shortly after the Civil War ended.

Present-day meteor-activity forecasters can learn a valuable lesson from the 1899 Leonid shower about setting their expectations. Citizens eagerly anticipated the November 1899 shower. Unfortunately, it came and went with the appearance of relatively few meteors. Astronomer Charles Olivier and others who had confidently predicted a spectacular showing were embarrassed and puzzled. Although the Leonids have a periodicity of 33 years, gravitational pulls from Jupiter, Saturn, and Uranus affect the path of the debris streams left by Comet Tempel-Tuttle, making accurate forecasting difficult.

These early forecasts, which relied only on the 33-year periodicity observed for generations, were well publicized in newspapers. Olivier wrote that their failure was considered "the worst blow ever suffered by astronomy in the eyes of the public."

Disappointed, the public lost interest in the Leonid meteor shower, which showed average rates of 15 to 20 meteors per hour throughout the early decades of the 20th century. A modest outburst of about 240 per hour occurred in 1932, but it was barely noticed. A shower that had once caused the country to face notions of the end of the



THE LEONIDS should put on a good show in 2006. One expert predicts North American observers may see as many as 100 meteors per hour streak across the sky November 18/19 from the shower's radiant in the constellation Leo the Lion. ASTRONOMY: ROEN KELLY

Bill Cooke is an astronomer with NASA's Marshall Space Flight Center located in Huntsville, Alabama.



A FISHEYE LENS
captures a wide-angle
view of several Leonid
meteors as they enter the
atmosphere and burn up
November 19, 2002.

JUAN CARLOS CASADO AND
ISABEL GRABOLEDA

METEOR SPEAK

METEOR

A small dust particle that appears as a bright streak of light when it burns up in Earth's atmosphere.

METEOR SHOWER

A flurry of meteors that appears to emanate from the same place in the sky over the course of a day or a few days. Meteor showers occur when Earth travels through a stream of debris left by a comet as it passes by the Sun.

METEOR OUTBURST

A brief period of meteor activity that surpasses a meteor shower's normal activity.

METEOR STORM

A great number of meteors (over 1,000 per hour) fill the sky over the course of a few minutes or hours.

METEOR STREAM

A stream of particles ejected from a comet during its passage around the Sun.

METEOROID

A small particle traveling through space.

RADIANT

The point at which meteors' paths intersect when traced backward.

SPORADIC METEOROID BACKGROUND

A steady rain of meteoroids that bombards Earth from all directions.

YARKOVSKY EFFECT

A rotating body in space is heated unevenly and, thus, the body radiates energy and momentum asymmetrically, which causes a gentle push that slightly changes its orbit; named after Russian engineer I. O. Yarkovsky (1844–1902).



THIS LEONID COMPOSITE
was taken November 12,
2002, in Australia (20mm lens
at f/1.8; five exposures of 10
minutes each). RUSSO MASSIMO

world was basically forgotten, observed only by the few meteor-obsessed souls who braved the cold November nights.

A new era

By the mid 1960s, the number of people observing the Leonids had dwindled even more. So, when the shower once again exploded into spectacular fireworks in 1966, very few people were outside to record the event, which occurred just before dawn over the desert Southwest.

About a dozen amateur observers noticed a jump in the meteor rate, with some 33 meteors observed between 2:30 and 3:30 A.M. The rate increased to around 190 in the following hour. Just after 5 A.M., observers saw 2 meteors per second, and the rate continued to rise. The storm's peak occurred a few minutes before 6 A.M., when observers saw 40 meteors per second — 144,000 per hour! The Leonid meteor shower had produced its most spectacular display — the “mother of all meteor storms” — and practically no one saw it. When word got out, public interest was piqued: Would there be a repeat in 1999?

By the late 1960s, this question became more than academic: The space era had begun. There were few satellites in orbit in 1966, but the number would grow to several hundred by 1999. Could they be damaged by an intense Leonid meteor shower?

Don't fear the Leonids

People on the ground have nothing to fear from the Leonids, or any other meteor shower. The fragile meteoroids completely burn up in the air due to frictional heating generated as the particles enter Earth's atmosphere. However, satellites orbit Earth above the atmosphere and are directly exposed to the incoming meteoroids. Would the Leonids (or any other meteor shower) constitute a significant risk to spacecraft?

Earth is constantly bombarded from all directions by a rain of meteoroids, a phenomenon scientists call the sporadic meteoroid background. Unlike this perpetual background rain, a meteor shower lasts a few hours or days and comes only from the direction of the radiant.

Space vehicles are designed to withstand the sporadic meteoroid background, but meteor showers can increase the danger. Whether or not the Leonids pose a significant risk to spacecraft depends on how many meteoroids there are relative to the sporadic background. If the number is small, so is the risk. If the number is large, the risk depends on the satellite's design. Space shuttles are somewhat vulnerable to meteoroids, which is why NASA does not schedule flights during meteor storms. The International Space Station, on the other hand, is so heavily armored against meteoroids and orbital debris that even a meteor storm does not threaten it.

The desire to protect satellites from a possible Leonid meteor storm in 1999 led to the most significant advancement in meteor science of recent decades — the meteor-stream technique, which is the basis for current meteor-shower forecasts.

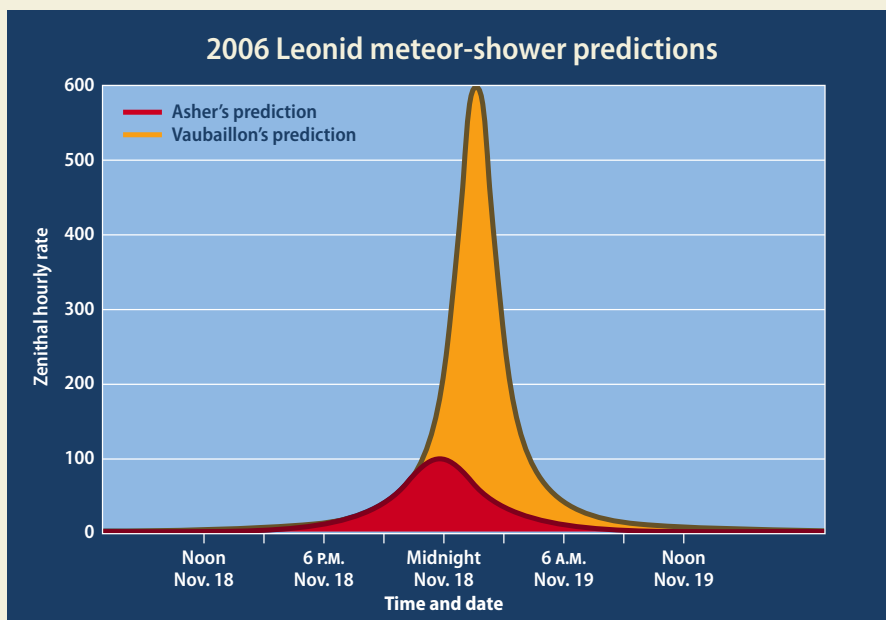
In principle, meteor-stream modeling is simple — create a computer model in which particles of various sizes are ejected from a comet, track their path through the solar system, and record how many meteoroids reach Earth's atmosphere and become meteors. Data from the model predict when the shower's peak will occur, how strong it will be, and, if you model millions of particles, how long the shower will last. In practice, however, it's a bit harder because some of the variables are not well understood.

Astronomers never know how many particles a comet ejects on its passages around the Sun; therefore, modelers use observations of past meteor showers to

HOW MANY LEONIDS WILL I SEE THIS NOVEMBER?

The table below gives estimates of the maximum number of Leonids per hour observers near select cities may see, assuming a clear and dark sky. Go outside around 11 P.M., make sure you are well away from any lights, and lie on your back or a lawn chair or sleeping bag. Be sure to dress appropriately for a cold November night. Use your eyes to take in as much sky as possible. Binoculars and telescopes are not of much use for observing meteors because of their narrow

fields of view. Why is there a significant difference between Jeremie Vaubaillon's and David Asher's forecasts? Vaubaillon predicts a maximum rate that occurs almost 2 hours later, which puts the radiant higher in the sky over the United States. A higher radiant results in more meteors being visible to observers on the ground. The Leonids are not predicted to be bright this year, so look for faint meteors, and don't expect many fireballs. — B. C.



HOURLY LEONID FORECASTS FOR SELECT CITIES

City	Asher forecast	Vaubaillon forecast
Atlanta	22	219
Chicago	21	208
Dallas	16	134
Denver	13	102
London	83	370
Los Angeles	7	44
Montreal	22	302
New York	31	298

EXPECTATIONS DIFFER by a factor of 6 for this year's Leonid meteor shower. David Asher of Armagh Observatory in Northern Ireland predicts an earlier maximum rate than Jeremie Vaubaillon

of Caltech's Spitzer Science Center in Pasadena, California. The earlier time means the shower's radiant will be lower and result in fewer visible meteors. ASTRONOMY: RICK JOHNSON, AFTER BILL COOKE

calibrate the model. Good observational data are hard to come by, especially from the 18th and 19th centuries. Also, debate continues as to which forces can change a meteoroid's orbit. Some modelers take into account non-gravitational forces like the Yarkovsky effect — a body rotating in space radiates energy and momentum asymmetrically, which causes a gentle push that slightly changes its orbit — whereas others consider meteoroids too small for this effect to be significant.

Despite these obstacles, meteor-stream models accurately predict meteor showers' timing — Leonid meteor-storm peaks have occurred within minutes of the predicted times. Models also have done reasonably well in forecasting showers' intensities, predicting Leonid meteor-storm rates in 1999, 2001, and 2002. The forecasts are not as accurate when shower rates are a few hundred per hour or less. In this case, the models often over-predict by 2–5 times.

Lion's roar or purr?

"What are the Leonids expected to do this year?" is a question I am asked beginning in January, and with increasing frequency as the mid-November meteor shower approaches. Everyone hopes for a spectacular celestial fireworks display like that which occurred in 2001.

Forecasts from various groups agree no Leonid meteor storm will occur this year, so don't count on a fireworks display. The background meteor rate should peak at about 20 meteors per hour on November 17. However, astronomers predict a moderate outburst may occur November 18/19 between 11:45 P.M. and 1:33 A.M. EST, timing which favors European observers.

In the United States, the radiant will be low in the eastern sky, which will reduce the number of visible meteors. Fortunately, the shower coincides with a waning crescent Moon, so moonlight won't interfere with the show.

How many meteors you can expect to see depends on whom you ask. Astronomer David Asher of Armagh Observatory in Northern Ireland predicts around 100 meteors per hour at the peak. Jeremie Vaubaillon of Caltech's Spitzer Science Center in Pasadena, California, forecasts a maximum rate of 600 meteors per hour. At first glance, this doesn't seem too bad — certainly better than the annual Perseid and Geminid showers, which are usually the year's best. However, the models also indicate this year's Leonid meteors will be less massive than in past years, which means they won't be as bright.

Even if the rate is as high as 600 per hour, the casual observer won't see many, because faint meteors are hard to spot, especially if you live in or near a city. If you want to see Leonids this year, you will need to find a dark sky. ■

ONLINE EXTRA

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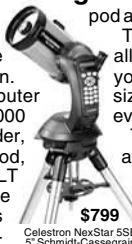
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Galaxies & The Universe: This 112-page soft cover helps you find hundreds of galaxies with scopes 8" and larger. Our part #A9573. Regularly \$19.95, it's sale priced at only \$6.50.

Eyepiece color filters for planetary observing for only \$14.95 each. There are 12 different Meade Series 4000

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And there are four similar value-priced Celestron filter sets for lunar and planetary observing. They have various combinations of color filters, a polarizer, and neutral density filters.

There is also a Meade ND9 neutral density filter for observing the Moon at \$16.95 and a green Celestron Moon filter for \$13.95.

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Red LED night vision flashlights protect your dark-adapted vision while you're observing. The Celestron variable brightness light (our part #VLED) is \$19.95. The Rigel Systems mini variable brightness light, #4393, is \$19.95. Rigel's larger water-resistant version (great if dewing is a problem), #4591, is \$24.95. The Rigel Systems two-color variable brightness mini (#4594) – a red light for reading star charts, and blue-white for setting up and taking down your scope – is \$24.95, while their larger water-resistant two-color version, #4592, is \$29.95.

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Put these handy pads under the legs of your telescope or spotting scope tripod and you'll virtually end the tremors that blur your view for a few seconds each time a breeze comes up or you touch the scope to focus. A set of three Celestron vibration suppression pads, our part #VSP, costs \$49.50. The set of Meade vibration isolation pads to the right, our part #895, costs \$49.95. Both sets will improve your observing and are well worth the modest investment.

Power to the people! Buy one Power

Tank instead of hundreds of flashlight batteries. Celestron Power Tank high capacity rechargeable batteries have the power to run your scope and accessories all night long. They can be recharged hundreds of times, saving you hundreds of dollars over the cost of buying flashlight batteries every few weeks. Each has two 12V DC cigarette lighter outputs; 3, 6, and 9V DC outputs for accessories; an emergency spotlight; built-in recharger; shoulder strap; carry handle; and more. The 7 amp hour Power Tank to the right, our part #4512V, is only \$59.95. A 17 amp hour Power Tank is also available for \$92.95.

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See more, pay less! The TMB Planetary eyepieces at \$99 may shake up your beliefs about how much you have to pay for a quality eyepiece from a famous designer. They were created by noted optics designer Thomas M. Back to complement the performance of the apochromatic refractors he designs that cost as much as \$92,990. When your scopes cost that much, you don't design eyepieces that limit their performance. And the 2.5, 3.2, 4, 5, 6, 7, 8, and 9mm TMB 1.25" long eye relief Planetary eyepieces won't limit the performance of your telescope, either, whether your scope cost \$92,000 or \$299.

Picture the planets for \$99. Take

your choice of a Meade LPI Lunar Planetary Imager, left, or a Celestron NexImage Solar System Imager, right. Each takes high magnification Moon and planet images with any telescope and sends them to your computer to view live or print out later.

If you want to add a useful accessory to the NexImage camera, consider the NexImage Reducer Lens at \$24.50. It doubles the field of view for wider lunar panoramas. Another accessory to consider is the \$57.95 NexImage 1.25" UV/IR filter. It gives sharper planetary surface detail with all CCD cameras.

Get a \$399 Deep Sky Imager Pro CCD camera for \$129 when you buy a Meade telescope.

The Meade Deep Sky Imager Pro CCD camera sells for \$399. But now, while supplies last, you can get the DSI Pro for only \$129 when you buy a Meade LX200, LX90, LX200, or RCX400 telescope!

The monochrome DSI Pro is loaded with features like NASA-developed "Drizzle" software that sharpens the resolution and quadruples the size of

your LX90, LX200, or RCX400 deep space photos. And the filter set for tri-color imaging, normally \$199, is only \$99 if bought with camera and scope.

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Non-magnifying red dot and bull's eye finders seem to project dots and circles of red light on the dome of the sky. They make it easy to aim your telescope or to star hop from object to object.

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I just wanted to thank you for the wonderful advice and service. This is the second major telescope purchase I have made through Astronomics, and it will certainly not be my last. You are always

available to answer questions and give excellent, and friendly, guidance and information. One couldn't ask for an easier or more pleasant experience.

Customer Quote of the Month #176

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PLANETARY OBSERVING

The elusive inner planet transits the Sun's disk for the last time in 10 years. /// BY MICHAEL E. BAKICH

Mercury crosses the Sun

Of the planets visible to the naked eye, Mercury, with its orbit closest to the Sun, is the most difficult to observe. On November 8, weather permitting and using a solar filter, you can watch Mercury in broad daylight as it crosses the brilliant solar disk.

Astronomers call the passage of one celestial body in front of another a transit.

Why transits occur

Mercury orbits the Sun at an average distance of only 36 million miles (58 million kilometers). Earth is nearly 3 times as far, so, from our perspective, Mercury always appears near the Sun. Several times each year, the planet appears either farthest east of the Sun (when Mercury's visible in the evening sky) or farthest west (when we see the planet in the morning sky).

Four — and occasionally five — times each year, Mercury passes between the Sun and Earth. Astronomers refer to this position as inferior conjunction. Superior conjunction occurs with Mercury opposite Earth as seen from the Sun.

On rare occasions — 13 or 14 times each century — we see Mercury cross, or transit, the Sun's disk. Transits of Mercury occur near May 8 or November 10. These two dates are special because they're when Mercury crosses Earth's orbital plane, the ecliptic. In May, Mercury crosses the ecliptic heading south, and, in November, the planet intersects the ecliptic moving north. If Mercury lies at inferior conjunction around these dates, a transit occurs.

Safety first!

Sunlight — especially focused through a telescope or binoculars — can blind you. To

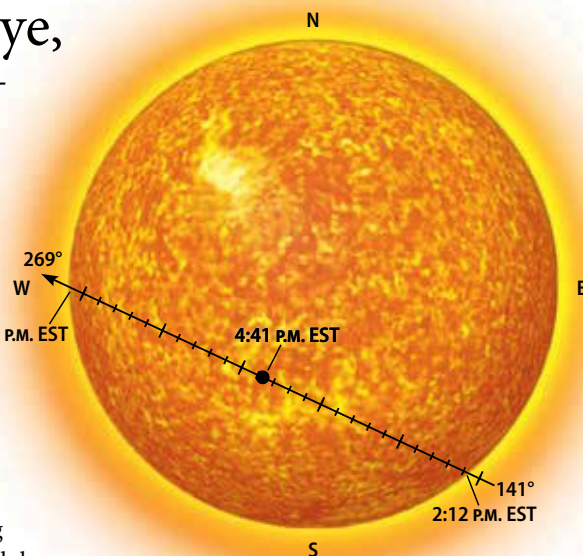
observe the transit, you'll need an approved solar filter. Several manufacturers sell filters made of aluminized Mylar film or specially coated glass. Make sure you place the filter at the front of your telescope, not at the eyepiece, and fasten it securely so a gust of wind can't dislodge the filter. This warning goes double for binoculars. Filter each lens.

Transit details

On November 8, Mercury begins its solar passage at 2:12 P.M. EST. Astronomers call this moment "first contact." Two minutes later, Mercury's entire disk appears against the Sun's (second contact). For the next 4 hours and 54 minutes, the black circle slowly crosses the brilliant solar sphere. Mid-transit occurs at 4:41 P.M. EST. At that moment, Mercury lies closest to the Sun's center — 7'03" away. At 7:08 P.M. EST, Mercury touches the Sun's eastern edge (which is to the west, or right, in our sky), marking third contact. Two minutes later — at fourth contact — the transit ends.

Because Mercury spans only 10" ($\frac{1}{180}$ the Sun's diameter), the best way to follow its trek is through a properly filtered telescope. Choose an eyepiece whose magnification nearly fills the field of view with the Sun's image. To select this eyepiece before the transit, target the Moon near its full phase. (Full Moon occurs November 5.)

You can spot the planet against the Sun's disk through filtered binoculars, but Mercury will appear tiny. In fact, at 7x or 10x,



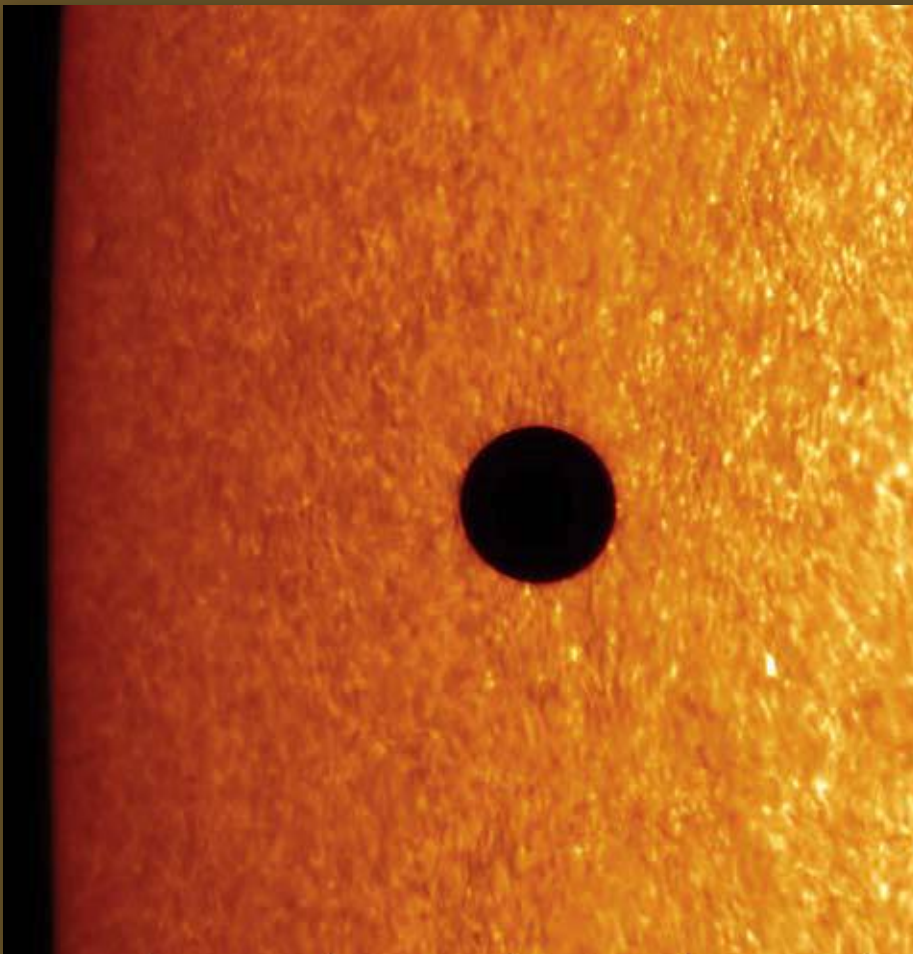
THIS DIAGRAM shows Mercury's path across the solar disk along with the transit's start, maximum, and end times. Remember, the Sun's eastern edge lies toward our western horizon, so Mercury will move from the lower right of the Sun's disk to its middle-left. ASTRONOMY: ROEN KELLY

you'll have trouble distinguishing it from a sunspot. Still, it's better to watch the transit through binoculars than not at all. Just wait 10 minutes or so, and you'll be able to pick up the planet's motion and direction.

At least part of the transit will be visible from the United States. People in the Eastern time zone will see the first 2 hours of the transit until the Sun sets with Mercury nearly halfway across the disk. Midwesterners will see all but the last hour of the transit, while western observers can watch the entire event through fourth contact.

Most people never have seen Mercury, so finding it in the morning or evening sky has its rewards. But to see Mercury during the day against the brilliant solar disk — that's the kind of event observers live for. ■

Michael E. Bakich is a senior editor of Astronomy.



MERCURY QUICK TAKES

- Mercury's **LAST TRANSIT** occurred May 7, 2003. Mercury's next transit is May 9, 2016.
- Mercury's surface has 299 **NAMED FEATURES**, 239 of which are craters.
- The **LARGEST CRATER** on any planet is Mercury's Beethoven, with a diameter of 400 miles (643 kilometers).
- From Mercury, the **SUN** is 63 times brighter than from Earth.
- The **SUN'S LIGHT** takes, on average, 3 minutes and 13 seconds to reach Mercury. At perihelion (closest to the Sun), this time drops to 2 minutes and 33 seconds, and at aphelion (farthest from the Sun) the travel time is 3 minutes and 53 seconds.
- On November 8, Mercury will **TRANSIT** the Sun. The event will start at 2:12 P.M. EST and end at 7:10 P.M. Observers under clear skies in the western United States can observe the entire event.

AS MERCURY crosses the Sun's disk November 8, it will appear as a small black dot, as it did in this Hydrogen-alpha-filtered image from May 7, 2003. Use an approved solar filter and an eyepiece that fills the field of view with the Sun's image. ROYAL SWEDISH ACADEMY OF SCIENCES



THE BEST VIEWS of the transit occur over New Zealand and the Pacific Ocean. Observers in the Americas and Australia will be well-placed to watch the event. ASTRONOMY: ROEN KELLY

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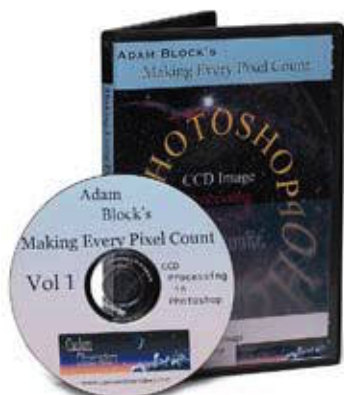
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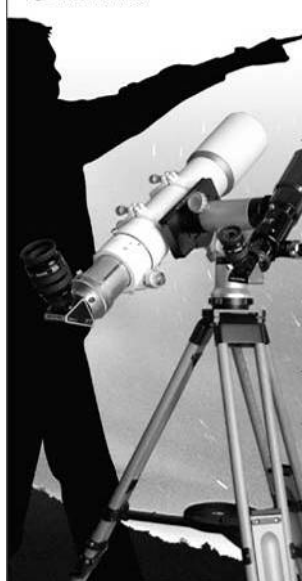
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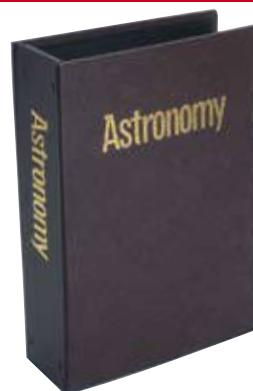
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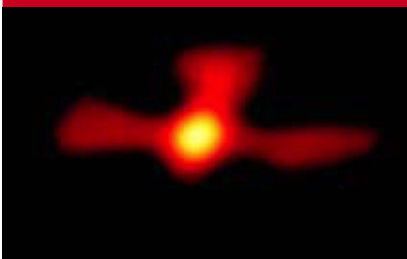
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Astronomy Associate Editor Laura Baird will accompany the group.

For more information, visit www.astronomy.com/tours.

OCTOBER 27-29

Volunteer State Star Party

Von Braun Astronomical Society dark-sky site, near Hohenwald, Tennessee. There won't be any organized daytime activities;

nighttime observing is the main focus of this star party. For more information, visit www.vbas.org/mlo.cfm.

OCTOBER 28

Astronomy Day: The Houston Way

The George Observatory, Needville, Texas. Held months after the traditional Astronomy Day celebration, the goal is to introduce people in the Houston area to observing. Visitors will have the opportunity to gaze through a 36-inch Gueymard telescope. For more information, visit www.astronomyday.org.

NOVEMBER 3

Far Out Friday at the Adler

Adler Planetarium and Astronomy Museum, Chicago. On the first Friday of every month, Adler hosts an evening of astronomy-related fun, including observing, lectures, planetarium shows, and tours of the facilities. For more information, visit www.adlerplanetarium.org.

NOVEMBER 6

Seminar: Hunting for Worlds around other Stars

Chabot Space and Science Center, Oakland. San Francisco State University Astronomy Professor Debra Fischer will present a non-technical overview of exoplanet discoveries: how they are detected, how our solar system compares, and the possibility for life elsewhere in the galaxy. For more information, visit chabot.space.org/visit/programs/lecture.asp.

NOVEMBER 8

Mercury Transit Viewing at the OMSI

Oregon Museum of Science and Industry, Portland, Oregon. Viewers throughout the Pacific Northwest are invited to view the transit through telescopes and listen to lectures about Mercury. For more information, visit www.oms.edu.

NOVEMBER 12

Astrofestival of Oslo

University of Oslo, Norway. This seventh annual event will feature an enormous solar system model, a space-alien hunt, a simulated surface of Mercury, and telescope workshops. For more information, visit www.astrofestival.no/english.php.

NOVEMBER 17

Bottomless Lakes Star Party

Bottomless Lakes State Park, near Roswell, New Mexico. Volunteers will provide guided tours of planets, constellations, and deep-sky objects. For more information, call Steve at 505.624.6058.

NOVEMBER 17-25

Chiefland Star Party

Chiefland Astronomy Village, Chiefland,

Florida. This event provides the opportunity to participate in the great activities members of the Chiefland Astronomy Village enjoy year-round. For more information, visit www.chiefland.org.

NOVEMBER 18

Family Astronomy

LodeStar Astronomy Center, Albuquerque, New Mexico. Geared toward families, this ongoing program will feature hands-on fun that covers a variety of astronomy topics. This month's session is "Leonid Meteor Shower." For more information, visit www.lodestar.unm.edu.

NOVEMBER 18

North Texas Skywatch Star Party

Lake Mineral Wells State Park, near Fort Worth, Texas. With a family-oriented atmosphere, this star party welcomes anyone interested in astronomy, regardless of experience. For more information, visit www.tarleton.edu/~planetarium.

NOVEMBER 20-DECEMBER 1

Conference: Canary Islands Winter School of Astrophysics

Cabildo Insular de Tenerife Conference Center, Puerto de la Cruz, Canary Islands, Spain. The theme for this year's event is "The Emission Line Universe." For more information, visit www.iac.es/winters.

DECEMBER 11-15

American Geophysical Union Fall Meeting in California

Moscone Center, San Francisco. This conference will provide an occasion for researchers, teachers, students, and consultants to discuss the latest issues affecting Earth and planetary science. *Astronomy* Editor David J. Eicher will attend. For more information, visit www.agu.org. ■

CONTACT INFORMATION

Please submit club announcements 5 months in advance to Coming Events, *Astronomy*, P. O. Box 1612, Waukesha, WI 53187, or jmcgovern@astronomy.com. Also use this e-mail address to submit your events for our online calendar.

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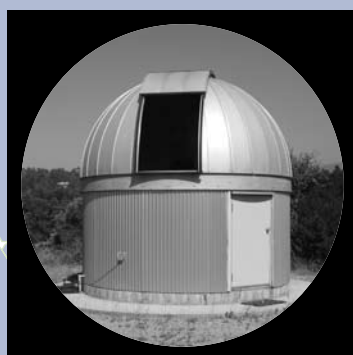
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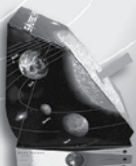
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LUNAR OCCULTATION

Stellar hide-and-seek

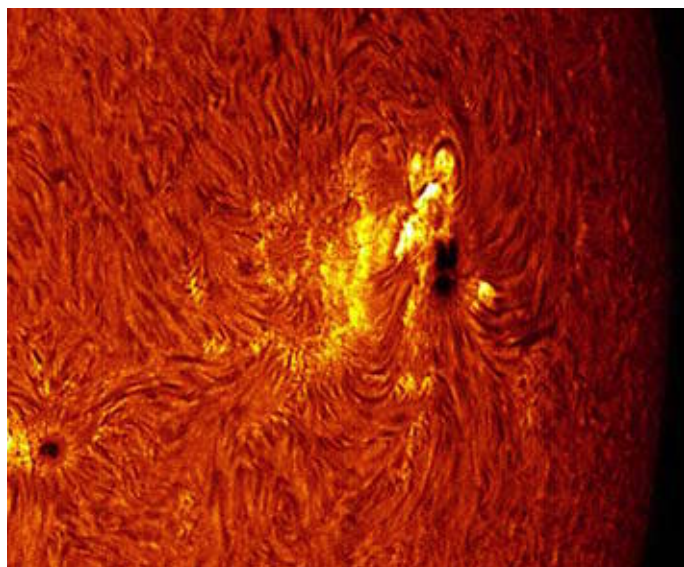
Lunar occultations (when the Moon passes in front of a star or planet) occur frequently. Usually, most of the stars covered are faint, and the Moon's brightness overwhelms them. Several times a year, however, the Moon's eastward trek through the sky carries our lone natural satellite in front of a bright star. The image above shows the 15th-brightest nighttime star — magnitude 1.04 Spica (Alpha [α] Virginis) — as it emerges from its occultation April 14, 2006. The Moon was nearly full during this event, which made visual observing of the occultation difficult.

▲ **SPICA REAPPEARS** (10-inch Hardin Optical Newtonian reflector at f/5, Imaging Source DFK31BF03 firewire video camera, taken April 14, 2006, between 17h13m and 18h03m UT) /// **RAYMUND SARMIENTO, QUEZON CITY, PHILIPPINES**



EMISSION NEBULA NGC 896 forms part of the Heart Nebula (NGC 1805) in Cassiopeia, where starlight reradiates as red light. (20-inch RC Optical Systems telescope at f/8.4, SBIG ST-10XME CCD camera,

LRGB image with exposures of 90, 15, 15, and 15 minutes, respectively) /// **SEAN AND RENEE STECKER/ADAM BLOCK/NOAO/AURA/NSF, KITT PEAK NATIONAL OBSERVATORY, ARIZONA**



THIS ACTIVE sunspot region produced two large X-ray flares in April 2006. Such activity is rare during solar minimum but should increase as the next solar cycle begins in 2007. (6-inch Astro-Physics 155 EDT apochromatic refractor at f/28, Solar Spectrum 0.2-Angstrom Hydrogen-alpha filter, Lumenera Infinity 2-1 CCD camera, taken April 6, 2006, at 14h00m UT) /// **GREG PIEPOL, ROCKVILLE, MARYLAND**



THE HELIX GALAXY (NGC 2685) in Ursa Major is an unusual object called a polar ring galaxy. Several star-forming filaments create a band centered on NGC 2685's nucleus. (16-inch RC Optical Systems Ritchey-Chrétien telescope at f/8.4, SBIG STL-11000 CCD camera, Astrodon Tru-Balance filters, LRGB image with exposures of 240, 60, 60, and 60 minutes, respectively) /// **DON GOLDMAN, ORANGEVALE, CALIFORNIA**



{ PHOTO JOURNEYS }

IT'S NOT OFTEN that four bright celestial bodies appear close in the sky. Here, the Moon, Venus (upper left), Jupiter (right), and Spica (Alpha [α] Virginis) lie within 5° of each other. The grouping sits above the Sierra Estrella Mountains, south of Phoenix. (Olympus OM-1 35mm camera, 100mm lens at f/4, Fuji Provia 100F slide film, 5-second exposure, taken September 6, 2005, at 7:31 P.M. MST) /// **JOE ORMAN, CHANDLER, ARIZONA**



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Orion Nebula/ Photographed with the Orion ED80 refractor and StarShoot Deep Space Color Imaging Camera. Courtesy Alan Smallbone

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